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ON THE COVER

8 SCI-FI MAGIC The force was definitely with artists at ILM as they created out-of-this-world effects for the seventh box-office hit in the *Star Wars* franchise, *The Force Awakens*.

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FEATURES

A NEW TWIST ON GAMING

There have been a number of watershed moments in video gaming over the past few decades. Third-generation systems in the mid-1980s introduced us to some of gaming's most iconic characters...Mario, Luigi, Zelda, Donkey Kong, and others. Sixth-generation systems – PlayStation 2, Xbox, GameCube – sparked the big console wars at the turn of the century, leading up to the last big showdown just two years ago.

That's when we were eyeing some added competition in the market, with newcomers trying their hand at developing new machines – most of which have been quiet of late.

Today, virtual reality has become this market's latest game changer. Visionary/Technologist Palmer Luckey set the gears in motion when he began working on the Oculus Rift head-mounted display, with others following suit. Palmer recognized the need for an inexpensive device that would open the doors for VR usage.

Just recently, the user stampede began for pre-orders of the Rift and, likely soon, pre-orders of the HTC Vive for use on Valve's SteamVR. In the near future, users will be stepping into the realm of virtual reality like never before, battling aliens, creating, interacting with fellow VR junkies, and watching movies and 360-degree entertainment from within a virtual cinema. (See Head's Up! on page 18 for a showcase of the VR HMDs presently in the spotlight.)

For those who could not wait for these two anticipated offerings, there is the rudimentary Google Cardboard and the robust Samsung Gear VR goggles that have quickly pushed this new trend into motion. And developers have been quick to respond with content – in fact, many of these earlier experiences could be tried at last year's SIGGRAPH. However, more (and presumably better ones) are just on the horizon, as updated development kits for the HMDs became available. Some of the HMD manufacturers have been working closely with developers (some even providing funding) to ensure that content will be available for the displays.

But hold on! Not so fast. VR is a fantastic technology for entertainment, learning, science, medicine, and so much more. But we need to be sure that this time around, as opposed to VR's last surge in the early 1990s, we are indeed ready to embrace VR as it is meant to be. This means that content creators need the necessary tools to create exciting experiences that will amaze us. This also means hardware that can process the high-resolution stereo imagery at 90 fps minimum with no latency for a responsive, immersive feel. (See the Viewpoint "Being the Hero in VR" on page 6, as Epic's Ray Davis gives his take on the new world of VR gaming.)

For most new users, this means a new PC, one specifically tuned to handle VR. This caveat could be a boon for PC makers, which have experienced a slump in recent months. It should also mean a boost for high-end GPUs from AMD and Nvidia, a requirement for these new PCs. So in the end, that $600 Rift could end up costing you $1,600 once you get that new computer to power it.

As for the displays that are geared specifically for a particular game system, well, expect a nice but somewhat limited experience – the VR display is dependent on the power of the console or, in the case of Samsung's Gear VR, the smartphone being used.

Despite these hurdles, VR is exciting. It opens new windows of opportunity for content creators and users. Indeed, 2016 is the year of virtual reality. When will you step into this new VR world? ■

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ACHIEVEMENTS HONORED WITH SCI-TECH ACADEMY AWARDS

Ten scientific and technical achievements represented by 33 individual recipients will be honored at the Academy of Motion Picture Arts and Sciences' annual Scientific and Technical Awards Presentation in February. In addition, the Society of Motion Picture and Television Engineers (SMPTE) will receive a special award recognizing a century of fundamental contributions to the advancement of motion-picture standards and technology.

"This year's honorees represent a wide range of new tech, including a modular, inflatable airwall system for composited visual effects, a ubiquitous 3D digital paint system, and a 3D printing technique for animation," said Richard Edlund, Academy Award-winning visual effects artist and chair of the Scientific and Technical Awards Committee. "With their outstanding, innovative work, these technologists, engineers, and inventors have further expanded filmmakers' creative opportunities on the big screen."

The Academy Awards for scientific and technical achievements receiving an Academy Certificate are:

Michael John Keesling for the design and development of Image Shaker, an optical system that convincingly creates the illusion of the camera shaking in a variable and repeatable manner.

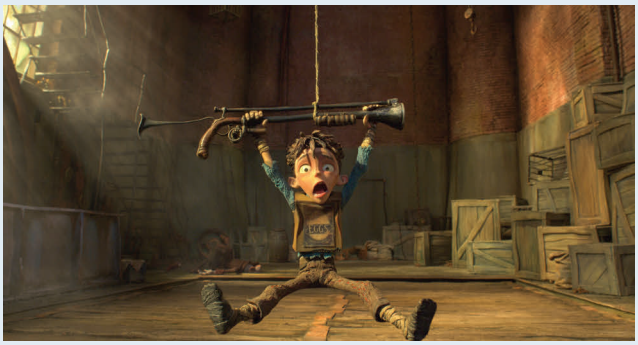
David McIntosh, Steve Marshall Smith, Mike Branham, and Mike Kirilenko for the engineering and development of the Aircover Inflatables Airwall.

Trevor Davies, Thomas Wan, Jon Scott Miller, Jared Smith, and Matthew Robinson for the development of the Dolby Laboratories PRM Series Reference Color Monitors.

Ronald Mallet and Christoph Bregler for the design and engineering of the Industrial Light & Magic Geometry Tracker, a novel, general-purpose tracker and solver.

Jim Hourihan, Alan Trombla, and Seth Rosenthal for the design and development of Tweak Software RV, a highly extensible media player system.

J Robert Ray, Cottalango Leon, and Sam Richards for the design, engineering, and continuous development of Sony Pictures Imageworks' Itview.



Keith Goldfarb, Steve Linn, Brian Green, and Raymond Chih for the development of the Rhythm & Hues Global DDR System.

Richard Chuang and Rahul Thakkar for the groundbreaking design, and Andrew Pilgrim, Stewart Birnam, and Mark Kirk for the review workflows and advanced playback features of the DreamWorks Animation Media Review System.

An Academy plaque goes to Brian McLean and Martin Meunier for pioneering the use of rapid prototyping for character animation in stop-motion film production.

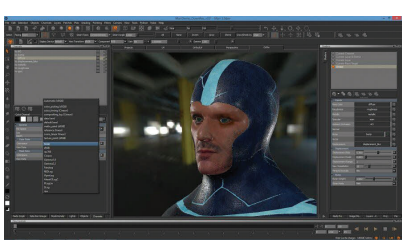
Another plaque is being awarded to Jack Greasley, Kiyoyuki Nakagaki, Duncan Hopkins, and Carl Rand for the design and engineering of the MARI 3D texture painting system.

THE FOUNDRY RELEASES MARI 3

The Foundry is now shipping Mari 3, the latest version of its high-resolution 3D painting tool. Mari 3 delivers new avenues for pipeline integration and productivity enhancing workflows that help 3D paint artists iterate faster, manage complexity better, and produce higher-quality results.

Some of the key features in the new release include: Modo rendering and texture baking directly from within Mari; APIs to integrate a user's renderer of choice; support for OpenSubdiv and FBX geometry; enhanced color space management workflows through OpenColorIO; an exposed node graph for advanced users; and integrated Arnold, V-Ray, Unreal, and Redshift shaders.

Pricing for Mari 3 starts at approximately $1,740.



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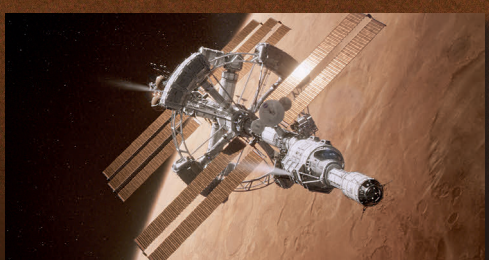

THE MARTIAN

EPIC HAS BEEN PUSHING THE BOUNDARIES WITHIN VR WITH ITS *BULLET TRAIN* EXPERIENCE.

BEING THE HERO IN VR

BY RAY DAVIS

One of the fundamental goals of game development has always been about bringing to life fantastic worlds that we otherwise would never get a chance to live in. From the very beginning, creating games has been about making the player become the hero (or even the enemy, occasionally), giving him or her the opportunity to live out the empowerment fantasy and accomplishing feats that were otherwise unattainable for most of us in the real world.

When something like VR comes along and gives us a whole new set of tools to build immersive experiences that completely trample anything we've been able to build before, it's not hard to see how game developers become instantly enamored with the potential in this emerging platform.

With VR, you get this amazing level of presence (for free!) that both gaming and film have been chasing since... well, forever. Classic gaming experiences, such as a first-person shooter, which have been the mainstay of games for many years now, almost seem absurd once you've seen what a VR first-person experience is capable of.

That presence, that immersiveness, is exactly what many developers have been chasing throughout the years with PC/console game development, and it's incredibly invigorating to see how VR will dramatically leap us forward in regard to what we're now able to create. I've yet to give a VR demo to a fellow developer who hasn't come out of the experience immediately churning out a hundred ideas of what we could do or what we should prototype next. The potential of this platform, even if not perfectly realized by today's hardware availability, is hugely attractive to anyone who is looking to build interactive digital content.

THE COST OF NIRVANA

Of course, the blessings of VR come at a steep price, and there are incredibly brutal obstacles to overcome for the seasoned game developer when building content for this new platform.

For example, in my career as a game developer, I've probably written at least a couple thousand lines of code aiming to manipulate and nudge cameras ever so slightly, to get just the right transitions or just the right framing in the various games I've worked on. For years, developers have worked to engineer and master these incredibly complex camera systems, since they were such a crucial tool to use in manipulating player attention and attitude.

But with VR, you can't touch the camera at all unless you're willing to risk making the player ill. All camera control is essentially gone with VR at this point. No longer can the developer simply grab your attention and force your view toward a specific point, to make sure you see some crucial plot point unfold.

Now we're forced back to the drawing board, to find new ways to encourage players' attention so that they witness the important events at hand. The price we end up paying for this whole new level of VR immersiveness

apparently is to have some of our most reliable and powerful game development tools taken away from us.

And to make it even more fun, these constraints aren't just limited to the design space! To build a compelling VR experience, you have to pay the extra computing cost for stereo rendering, which naively equates to nearly twice the rendering cost for a single frame in previous games. On top of that, we've discovered that compelling VR requires consistent high frame rates to avoid causing significant discomfort for viewers.

With the last console generation upgrade, most developers in the industry were grudgingly making the transition from building 30 fps games to 60 fps at 1080p resolution. This may not sound like much, but it actually ends up being a considerable challenge from a technical point of view. Then VR comes along and demands even more – render every scene twice for stereo and then run at a guaranteed 90 fps!

Going from the mentality of aspiring to hit 30 fps "most of the time" in the last generation to now unfailingly needing to hit 90 fps to prevent people from becoming ill turns out to be a monumental leap in engineering effort.

NEW LEVEL OF GAMING

Fortunately, though, we've already found these constraints and trade-offs to be absolutely worth it. For the first time in a long time, I find myself once again passionate about solving really hard problems in building VR games. There's so much undiscovered ahead of us for this new platform, and I'm absolutely excited that this year, in particular, we'll see a massive influx of new creative talent, now that more people can finally get their hands on VR hardware.

EPIC'S *SHOWDOWN*, A VIRTUAL-REALITY EXPERIENCE, IMMERSES USERS IN THE MIDDLE OF A STREET BATTLE.

Both veteran and newcomer developers alike are once again put on equal footing, and we're put in a situation where the best idea will win – nobody knows quite what that is, but everybody is welcome to try to figure it out.

Furthermore, the VR development community has been incredibly open and forthcoming with their own prototypes in learning. It's as though everyone recognizes that nobody actually knows what they're doing yet with VR, and so we might as well all share our successes and failures in an effort to help one another figure it out that much quicker. It's incredibly refreshing as a developer, especially when, in recent years, many other developers may have been more focused on making money rather than on making something novel and new.

One other unexpected add-on of the VR platform emergence is the surge of new interaction models that are coming on-line in support of it. HTC (along with partner Valve) somewhat surprised the industry at GDC 2015 by announcing its motion controllers alongside its Vive HMD. And then not long after, Oculus was quick to showcase its own motion controller answer along with some really compelling content.

Out of this particular case, I believe we've somewhat accidentally identified the minimum requirements for a truly immersive VR experience – high-quality head-mounted displays plus some form of motion-tracked controllers. Without that form of 1:1 input, you're left shoehorning previous forms of archaic input into the new VR medium, and it quickly becomes kludgy, reminiscent of the early days of touchscreen mobile games, when developers thought that virtual D-pads (directional pads) would be a good idea (or at least good enough).

Clearly, mapping physical D-pads to tiny touchscreens didn't work out so well, and it wasn't until developers started really embracing the capabilities (and limitations) of the touchscreen that we started to see some of the defining experiences for mobile.

Motion controllers for VR feel as if they are very much in the same situation in this particular instance, and without being able to use my hands directly with VR, it's hard to not feel severely handicapped.

Will we discover the killer app of VR in 2016? Maybe not, but I can guarantee we'll absolutely see some truly amazing games this year. And probably some really astounding evolutions of storytelling from the film industry brought to VR, as well. Maybe there also will be some novel ways for us to communicate, with each leveraging VR. Who knows?

Or is VR really so boring that any development will only find life in enterprise settings? I doubt it, but no matter what, I'll be there along with every other passionate developer, trying to figure out all the cool, new things we can do with VR, learning and sharing everything along the way.

VR will consume and replace all our other methods of interacting with technology. It's simply a matter of time as to when we're ready to embrace it. ■

CGW.COM VIDEO: GO TO EXTRAS IN THE JANUARY.FEBRUARY 2016 ISSUE BOX

Ray Davis is the manager of Epic Games' West Coast studio, driving developer relations, evangelism, and support for Unreal Engine. He is also Epic's VR strategist for the Unreal Engine.

SCI-FI MAGIC

ARTISTS AT ILM CREATE AWARD-WINNING EFFECTS FOR THE SEVENTH BOX-OFFICE HIT IN THE *STAR WARS* FRANCHISE

BY BARBARA ROBERTSON

CGW.COM VIDEO: GO TO EXTRAS IN THE JANUARY.FEBRUARY 2016 ISSUE BOX

An enviable combination of critical acclaim and box-office returns has catapulted *Star Wars: The Force Awakens,* the seventh episode in the Lucasfilm series, into the record books. In less than a month, the Disney/Lucasfilm sequel rocketed into number one at the box office, becoming the highest-grossing domestic release in history. After four weeks, it had earned $1.8 billion globally, with the China market just coming on board.

A scan of reviews on Rotten Tomatoes, where the science-fiction action-adventure achieved a 93 percent positive rating, shows little if any mention of the visual effects. No complaints. No praise. One critic actually extolled the filmmakers' success in avoiding "the deficiencies of those latter films: the orgiastic overuse of CGI."

Another critic raved about BB-8: "The simple design is ingenious and how wonderful that he/it is not computer-generated but of our world."

But, *Star Wars: The Force Awakens* has CG effects in 2,100 of its 2,500 shots, a proportion closely matching the number for each of the three prequels. And, BB-8 is digital perhaps a third of the time in the film.

No wonder the feature has received Oscar and BAFTA nominations for best visual effects, and seven VES nominations. In addition, it received the AFI award for movie of the year.

In the run-up to the film's release, numerous articles talked about the practical effects. Few, if any, mentioned CG. Finally, on January 15, the day after *Star Wars: The Force Awakens* received a visual effects Oscar nomination, Disney released a video showing before and after visual effects shots. Greenscreens? Yep. From the first scene of Rey scavenging. The "Millennium Falcon"? Digital. The TIE Fighter sinking into the sand near the beginning? The sand in the background is real, but the ship and sinking sand are digital. Maz's castle? Digital. That lightsaber battle? The entire forest surrounding the actors is digital. The explosions? A combination of real pyro and CG simulations. And the final battle, surely to no one's surprise, has all-digital shots.

How did the artists at Industrial Light & Magic achieve the sleight of hand that convinced viewers and critics what they were seeing was real – or at least as real as the first three films?

The answer starts with Roger Guyett, visual effects supervisor and second unit director. This is his fourth film with Director JJ Abrams, fifth if you count a brief bit of help with *Super 8.*

"[JJ and I] were in the process of finishing *Star Trek* when he said yes to [Producer] Kathy Kennedy," Guyett says. "Thankfully, he asked if I was interested. Once *Star Trek* came out, we were on *Star Wars* full time. I went down to LA once or twice a week. We talked a lot about the tone and style we were trying to capture."

Guyett had been a visual effects supervisor for *Episode III*, and was keenly aware that for the seventh episode, people wanted something with more of the flavor of the first films, *Episodes IV, V, and VI*.

"I'm incredibly proud of the work we did on *III*, and have fond memories of working with George [Lucas], who was inspirational, with an incredible imagination," Guyett says. "But on this one, we wanted to recapture more of the tactile, visceral quality of the early films. We wanted to find the right balance for the fans between historically

correct with the right levels of respect and diligence, and at the same time bring something new and exciting. A lot was done practically. But, a lot is digital. The trick wasn't worrying about approaches. It was the end result. To convince the audience that what they were seeing was really unfolding."

Also joining the project early from the VFX side were the previs team at Halon led by partner Bradley Alexander, and the modeling team at ILM led by David Fogler, asset build supervisor.

Alexander adds, "We started around October 2013 and jumped right into talking with ILM to figure out file formats and scales that would work, so what we handed over would be nice and tidy. They gave us assets, and we also built a lot."

SHIPBUILDERS

Fogler and his team began working on the assets in Autodesk's Maya soon after Fogler started on the project, also in October 2013.

"I was 10 years old when I saw the first *Star Wars [Episode IV],* and I was blown away," Fogler says. "What struck me was the aesthetic. The dirty, worn, rusty, real world. I could relate to it. It has stuck with me to this day. It fed all my decision making for the *[The Force Awakens]* world."

One of Fogler's first jobs at ILM had been building practical models for *Star Wars Episode I,* and continued that work for *Episodes II* and *III*. He became a digital modeler for *Pirates of the Caribbean: Dead Man's Chest,* and went on to receive five VES nominations and two awards (*Transformers* and *Transformers: Dark of the Moon).*

"Finding the balance between old and new was hard," Fogler says of the modelers' work on *The Force Awakens*. "In building our new versions of these ships, we had to figure out the collective memory of those ships and then decide where to take them. We'd have conversations about what these things looked like. Was the Star Destroyer white or gray? Well, it was white in the film but gray on stage. We'd look at the old miniatures. We'd look at them on-screen, and then plug that information into our new matrix."

For the "Millennium Falcon," Fogler scanned a five-foot-long miniature built for *Episode IV* and created a mechanically logical digital version to match. "If you squint at it, it looks like the five-foot miniature," Fogler says. "But, you can look at full-scale details a foot away."

In addition," Fogler says, "we designed and built the Star Destroyer, which is huge. It's bigger than the Super Star Destroyer in *Empire*, more armored feeling, sleeker. We tried to strike a balance between things that looked photoreal but did not feel foreign to the miniature work done before. Our Star Destroyer could have been built as a miniature."

As for practical ships, the production team built full-scale TIE Fighter and X-Wing ships, which were used on location. The ILM modelers scanned and photographed those models to create digital versions.

"Ours needed to function mechanically and work in multiple lighting environments," Fogler says. "The camera gets very close to our builds."

PREVIS

Meanwhile, Halon's artists previs'd that short, early sequence in which Rey digs through a Star Destroyer and jumps down a rope, and then began a more complicated sequence with the TIE Fighters and the "Millennium Falcon" – a desert chase sequence through the graveyard of starships.

"Roger Guyett pretty much

ANYTIME A SPACESHIP IS IN THE AIR, IT'S COMPUTER-GENERATED, AS IS THIS X-WING.

HERE, TIE FIGHTERS ARE SHOWN AGAINST THE SUN IN AN ALL-CG SHOT.

held our hands as we figured out what JJ [Abrams] wanted," Alexander says. "Once we got the script, we started building the foundation shot by shot. Then my whole team met with JJ, which was cool. We ended up with a good starting point for a sequence before everyone left LA for London. I previs'd the shot when the 'Millennium Falcon' flies up into the sky, twists, and does an inverted U-turn. When I saw the final shot with the John Williams score, I got tears in my eyes."

Halon artists in LA also previs'd the TIE Fighter escape from the hanger and the Stormtroopers' attack on the village. Then, Alexander followed Abrams and Guyett to London.

"They filmed pretty much everything in the village attack in London and the hangar sequence," Alexander says. "They shot some of the desert chase in Abu Dhabi. The interior of the 'Falcon' was in London, but the exterior was mostly CG."

The Halon team continued working on previs through production and well into postvis (see "Postviz," page 14).

"We use the previs and storyboards to flesh out ideas," Guyett says. "But on the shoot, we invent new ideas."

Those ideas sometimes resulted in blank cards within edited footage.

"You'd look at an edit of a sequence and there would be an actor on bluescreen reacting to something," says Halon Senior Previsualization Supervisor AJ Briones, "then there would be a few seconds of black cards with 'action' written on them."

At ILM, Animation Supervisor Paul Kavanagh helped design shots that would replace those black cards. With the exception of the CG characters Maz and Supreme Leader Snoke, a CG creature, and digital doubles, the primary focus for the animation department was shot design and ship animation for the all-CG sequences – the desert chase with the "Millennium Falcon" and TIE Fighters, the TIE Fighter escape from the hangar, the shots with ships traveling between locations, and an extensive battle between the X-Wings and TIE Fighters in the third act.

ANIMATION

"Nowadays we see CG ships and creatures doing impossible things for the sake of spectacle," Kavanagh says. "It's tempting to go over the top with CG. But we wanted the feel of the original."

To get that feeling and honor the director's guidelines, the animation team relied on Guyett, Halon, the original films, and advice from artists at ILM who were on the original crews.

"Roger [Guyett] had a real grasp of what JJ [Abrams] wanted as far as shot design," Kavanagh says. "We had a lot of previs from Halon. And, we looked at the old movies. We went back to the original trilogy and looked at the motion-control work as a guide to what we should do. They had restrictions on how fast the miniatures could travel. The longest motion-control track was 60 feet, and the camera could go back only so far in the building. We took some liberties, but the 'Millennium Falcon' doesn't fly 2,000 miles per hour."

During postproduction, Dennis Muren would often look at the work done by ILM's artists and animators, and give advice. Muren had worked on the first *Star Wars*, received Special Achievement Awards from the Academy for the second and third, *Star Wars: Episode V – The Empire Strikes Back* and *Star Wars: Episode VI – Return of the Jedi*, a Technical Achievement Award, and six more Academy Awards for best visual effects.

"He would come every week," Kavanagh says. "He might say, 'Yeah, that's how I would have shot it.' Or, he might have a different idea. He gave us a mini presentation about how they did the ships and camera moves for the original trilogy. The lenses they used. The depth of field. It was fantastic."

Kavanagh's team included 25 animators in ILM's San Francisco studio, six in Vancouver, 12 in London, and 10 in Singapore. He also worked with animators at Base FX and Hybride. Singapore animators handled the TIE escape sequence, some face replacements for digital doubles, and a cute moment between BB-8, R2-D2, and C-3PO. ILM London animators worked on the two CG characters, Maz and Snoke.

"The San Francisco team did everything else," Kavanagh says. "The 'Falcon' chase. The spaceship sequences. Animators in Vancouver basically worked as an extension of San Francisco."

CG CHARACTERS

To better achieve the nostalgic look they were after, the filmmakers used puppets and prosthetics for most of the alien creatures, many of whom appear in Maz's bar in her castle.

Maz (Lupita Nyong'o), however, is CG, as is Supreme Leader Snoke (Andy Serkis). The animators had motion-capture data for both.

"The actors gave great performances," Kavanagh says. "They were so good, we wanted to make their performances come though the characters. We've done a lot of that at ILM; we have a system."

The crew captured Serkis at his Imaginarium studio in London and on set. Facial capture was most important for this character, which rarely leaves his elevated chair. Maz, however, was a tiny, wizened character with facial features that differ greatly from Nyong'o. For her, the ILM crew relied more on the Medusa system from Disney Research to capture a library of expressions that modelers converted into shapes on the 3D model. Then, rather than apply motion capture directly onto the model, the animators matched high-resolution video of Nyong'o's performance, much as animators had done to create the character Davy Jones in *Pirates of the Caribbean.*

For the digital double of BB-8, animators matched that character's performance as well – that is, the performance of the practical droid puppeteered on location. However, Kavanagh was instrumental in giving the lovable droid its first moves. He put a simple rig into the CAD model used to build the practical robot, and did quick animation tests for Abrams.

"I had his head sort of lead the big ball," Kavanagh says. "His head would go down first, and then he'd rock back to stop himself. I showed that to JJ, and he liked it." The rest of BB-8's personality developed as the puppeteers had the droid interact with the actors, but in the film, he is sometimes digital.

"There's a shot where he's spinning inside the 'Falcon' and falling around until he supports himself with grappling hooks," Kavanagh says. "We put him in the back of ships. Also, in some areas, it would have been harder to paint out low material on the ground than to use a CG version. The guys in modeling and look development did such an amazing job on BB-8; once he's rendered, you can't tell he's CG."

Animators also performed the Rathtar, a vicious creature with eight arms, suckers, and a giant mouth filled with gnashing teeth.

"We couldn't use too much simulation and still have it live in a world of foam latex creatures," Fogler says. "Animators provided the balance."

(TOP TO BOTTOM) MODELERS REFERENCED "MILLENNIUM FALCON" MINIATURES FROM THE ORIGINAL *STAR WARS* TO CREATE THE CURRENT CG MODEL. TIE FIGHTERS CHASE THE "FALCON" OVER A DIGITALLY RECONSTRUCTED DESERT. THE CASTLE, X-WINGS, SPARKS, AND DESTRUCTION ARE ALL DIGITAL.

ENVIRONMENTS

In addition to building and performing spaceships and a few CG characters, the artists

When you need to render in less than 12 parsecs....

POSTVIS

Halon artists created previs and postvis for *Star Wars: The Force Awakens*, working with Director JJ Abrams and Visual Effects Supervisor Roger Guyett. Sometimes the lines between previs and postvis blurred.

"You think of postvis as getting footage shot on the day in which something needs to happen – a set extension or CG element – so the editors can make a cogent story," says Senior Previsualization Supervisor AJ Briones. "Or, you might combine plates. But, there are also CG shots that haven't gone through previs, so a lot of post is still previs."

Briones gives an example from the third act.

"We added set extensions and temporary lightsabers to the plates for the lightsaber battle," Briones says. "At the same time, we were doing postvis on the space battle between the X-Wings and TIE Fighters to track the camera, add snow, take out bluescreens, and extend the shots."

And then one day, in between shots in the edited footage, Briones saw a black card.

"It said something like, 'The planet explodes. As it explodes, it turns into a sun,' " Briones says. "That was a lot of fun, challenging. You relish the opportunity to do those shots. When I was a kid playing with *Star Wars* toys, I never imagined I'd be flying those things in a real film. It was pretty surreal."

SUPREME LEADER SNOKE IS CG, PERFORMED BY ACTOR ANDY SERKIS AND ANIMATED AT ILM LONDON.

at ILM also created massive environments – set extensions and all-CG environments.

"There were a lot of fantastic locations," says Visual Effects Supervisor Pat Tubach. "When we created the 'Falcon' chase sequence, because the ship is flying at high speed, we had to re-create a lot of that environment. We had a ton of plates shot in Abu Dhabi, and Roger [Guyett] shot a lot of aerial footage. We used some in shots, some as reference, and some as projections for our digital environments."

Tubach worked with Guyett, as he had done on previous films, to manage the crew of approximately 200 artists in ILM's San Francisco studio, 75 in Singapore, 75 in London, and 75 in Vancouver, as well as the work done by 80 artists at Abrams' Kelvin Optical, and at Base, Hybride, and Virtuous.

The photography and scans of the desert in Abu Dhabi, where the village battle, the desert chase, and other sequences on Jakku take place, gave the artists at ILM what Environments Supervisor Susumu Yukuhiro calls a "recipe for the environment.

"We knew how the sky looks, how colors reflect on the dunes," Yukuhiro says. "You think you know what a dune looks like, but the sun on particles of sand creates weird colors."

To make the desert dunes, the artists sculpted 3D shapes, and then projected photography on top. Because the geometry was so complex, Yukuhiro began experimenting with Isotropix's Clarisse iFX.

"That worked fantastic," Yukuhiro says. "Throughout the show, the geometry is big and heavy, but we didn't have to optimize or make proxy versions of the environments. Clarisse doesn't do modeling, but we could bring in 3D geometry, interactively light it, interactively place things in the environment, and then render it. It was a really great way of working."

Yukuhiro counts the 'Millennium Falcon' chase through the desert graveyard as the team's most challenging.

"It was not a technical challenge," Yukuhiro says. "It was an aesthetic challenge. We weren't making another sci-fi movie; we were making *Star Wars*. Not the prequels, the original *Star Wars*. *Star Wars* has iconic shots that are about simplicity, not complexity. For example, in one of the first sequences, there's a shot of the speeder bike. The camera pans and we see the Star Destroyer in the desert. It's a simple flat shot with the iconic silhouette of the Star Destroyer. We did that shot four times. We really pushed that look."

A second major location was Maz's castle. The filmmakers shot footage for that sequence in the back lot at Pinewood Studios outside London.

"There was no actual castle," Tubach says, "only a destroyed version. So we reverse engineered how it was oriented and worked out what it looked like. Then, using plates from the Lake District in England, we created a picturesque English countryside location with a beautiful, ancient castle. Of course, we then had to figure out how to bring it down in an interesting way." (See "Believable Destruction" on page 16.)

Trees in the background were a combination of photo elements and CG trees. "Anytime a tree moves, we created it in Speedtree so we could animate it," Yukuhiro says. "Also, the grass."

The largest environment was the Starkiller base planet, which the ILM artists created by

extending plates shot in Iceland and creating fully CG worlds.

"Instead of having a base on top of a planet, the First Order went to that mind-blowing level where they dug in and built the base inside the planet," Tubach says.

The environments team again relied on Clarisse for shots of the 'Falcon' landing on the snowy planet, rendering the ships with a Katana-to-RenderMan pipeline and the environments in Clarisse.

"We had a lot of full-CG shots, but because we had photographic reference and because JJ [Abrams] wanted a practical, nostalgic look and feel, we also did a lot of 2.5D matte paintings with photo projections," Yukuhiro says. "We worked closely with effects. They could take our scene, add effects, and place lights interactively. It was a really good way of working."

PULLING IT ALL TOGETHER

At the end, as always, the compositing teams create the final images, and for this film, Compositing Supervisor Jay Cooper led a team of ILM artists who worked on 1,200 shots. Abrams' Kelvin Optical composited the rest. Thirty artists in San Francisco handled 60 percent of ILM's shots, with 15 artists in London and 18 in Singapore taking the other 40 percent.

"There was a concerted effort to make this film feel like the originals, which were optical, with hand-drawn elements, rotoscoping, and glass matte paintings," Cooper says, "and, of course, tons of models. We wanted to bridge the past and make it feel like those films, but not antiquated or anachronistic. No one was in any rush to go back to matte lines."

To achieve that look, Cooper and his team worked in The Foundry's Nuke with deep compositing. Hundreds of layers. With each shot, they tried to tease out elements they thought were important in the past.

"Our goal was to make the film look organic, whether through lens flares, dirt, or grime," Cooper says. "When people think of CG, they think of clean, antiseptic, razor-sharp edges."

For rendering, various artists on the teams used Clarisse, Pixar's RenderMan, Chaos Group's V-Ray, and Solid Angle's Arnold.

"It's whatever knives the chefs bring to the kitchen," Cooper says. "It's what artists feel comfortable with. There are things, obviously, like real-world rendering and environment lighting, that are huge helpers in the way you get the right falloff and the right reaction to materials. But at the end of the day, it's an artistic process. We noodle everything – does this feel too sharp? Does it look too metallic? Too plastic? We have a matte painter on the show, Paul Houston, who has been doing this for 40 years. We reviewed shots with Dennis Muren and [longtime, award-winning VFX Supervisor] Scott Farrar. Getting feedback from people like them is worth way more than any tool."

Star Wars' nomination for best visual effects affirms

(TOP) ARTISTS AT ILM EXTENDED FOOTAGE SHOT ON SET WITH DIGITAL ENVIRONMENTS. (BOTTOM) EVERYTHING IN THIS SHOT EXCEPT THE ACTORS IS CG.

the success this team had in achieving their goal.

"JJ [Abrams] wanted this to be a film that looked like it could have taken place during the original trilogies, but he didn't want to ignore modern filmmaking techniques," says Tubach. "The idea was to marry current technology and techniques into the old-school techniques, to maintain the legacy of the project."

Given the studio's history and high level of artistic skills, they were probably the only ones who could. ■

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BELIEVABLE DESTRUCTION

Effects TD Supervisor Daniel Pearson led a team of 24 artists in ILM's San Francisco studio, four in Singapore, 14 in Vancouver, and four in London who created fire, water, smoke, dust, explosions, and tons of destruction – ships blown apart, buildings collapsing, planets exploding – for *Star Wars: The Force Awakens.*

"On this project, fire, water, and smoke were grid-based simulations using proprietary software based on the FLIP solver. We used our proprietary tool called Plume, our Zeno particle system, and for certain effects, [Side Effects'] Houdini. Because we didn't have many water effects, we simulated them inside Zeno and rendered inside Houdini," says Pearson.

In addition, the creature development team handles some simulations.

"We do cloth-, flesh-, and spring-based simulations on top of our rigid-body simulations," Pearson says. "That gives them bending and tearing. So their work overlaps what we do. We have a mix of both."

For destruction, however, the effects team wanted a new technique that would be faster, better, and easier for the artists.

"The big destruction shots are usually the last to finish because they're so complex, so that gave us the lead time to build a new system, refine the pipeline, and solve issues," Pearson says. "Rick Hankins, effects TD and R&D engineer, came on early and probably spent a year in development. He wrote a position-based dynamics system (PBDyn)."

Pearson explains how the new system works: "It takes a set of positions and, based on contact with neighbors, solves constraints. Constraints might include friction, attraction, and repulsion. We also have a shape-matching constraint so groups of particles react like rigid bodies. We can set different strengths for the constraints. The positions are calculated first. It derives velocities from where the points move."

Before, the simulation system the team used treated velocity within one continuous volume. When applied in one area, the rest of the grid would compensate to reach equilibrium. With PBDyn, the simulation is more akin to spheres in space. As they touch, they exert forces on each other, and the constraints dictate how they act when that happens. As a result, one simulation can handle multiple levels of detail and material types.

"We start with every particle having the same set of constraints," Pearson says. "Friction determines how far one point can rub against another before it slows down. Repulsion makes sure they all stack on one another. Shape matching on a subset of particles moves bigger groups as one unit but with single constraints on individual particles. That way we can have dry dirt on top of a rigid body, and snow on top of that – a set of particles that stick together and operate in the same simulation at the same time."

Hankins developed a pipeline around the system so that it can procedurally generate the rocks, snow, and so forth based on models from the modeling group or the generalist [digital matte-painting and environments] group.

A simulation might start with a big chunk of rock populated with particles. Voronoi partitioning breaks the rock into big and small chunks distributed in organic ways.

"Then, we manipulate the data to erode certain sections based on edges and distance to the ground surface," Pearson says. "That creates dirt. We defined other areas based on distance from the surface as snow. It's meaningless to the simulation – it's just a different setting on the attraction constraint."

In practice, an animator might block in the destruction over time – the ground breaking apart, for example. The TDs could use that as a visual reference or, sometimes, as a raw footprint.

"In one sequence, the ground is collapsing," Pearson says. "Animators roughed that in to show which sections should collapse at a particular time. We used those models to drive the sim at first. Then, we decided to use them as a visual guide instead, to make updates easier."

For rendering these large simulations, the crew used Clarisse.

"Clarisse can handle massive amounts of geometry," Pearson says. "It was great."

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HEADS UP!

HEAD-MOUNTED DISPLAYS ARE A MUST-HAVE FOR EXPLORING IN VR SPACE

BY KAREN MOLTENBREY

On your kayak trip down the Grand Canyon, it's a good idea to have a waterproof pack. For hang gliding in Rio de Janeiro, a helmet sure can stave off an injury. For strolling along sandy Hawaiian beaches, sunblock can stop a burn. No matter where your next adventure takes you, it's a good idea to be prepared. But if you are exploring fascinating destinations in virtual reality, the proper equipment isn't just a good idea, it's a necessity.

While there are all kinds of peripherals to make the virtual experience more immersive (gloves, headphones, and so on), there is one that is a must-have: a head-mounted display (HMD).

VR headsets block out external light while projecting an HD stereo image on the screen right in front of a person's eyes. Humans have a field of view (FOV) of about 180 degrees, and most head-mounted displays in development have lesser amounts – some more so than others. However, the higher the FOV, the greater the sense of immersion and situational awareness in the virtual world. Other important factors to consider are resolution, for a crisp, clear view, tracking accuracy, motion synchronization, and refresh rate, to keep that nausea at bay.

Head-mounted displays have been used for quite some time in science, military, medical, engineering, and other high-end market segments where VR applications are prevalent. In the past year or so, however, we have witnessed a growing interest in VR, particularly at the consumer level, spurred by the development of affordable equipment, including headsets, that cost a fraction of the price today versus the early 1990s, when VR experienced its last surge.

This new affordable cost opened the door to mainstream VR, which began when Oculus started whetting the appetites of gamers with beta versions of the Oculus Rift a few years ago. When Facebook purchased Oculus in 2014, the feeding frenzy began.

Today there are a number of headsets either on the market or poised for availability in the very near future, with the promise of many others to come. Some are expensive, high-end devices that are clearly meant for professional use, while others – highlighted here (using the most currently available information available at deadline), in order of expected availability – are geared for consumers and gamers.

CARDBOARD

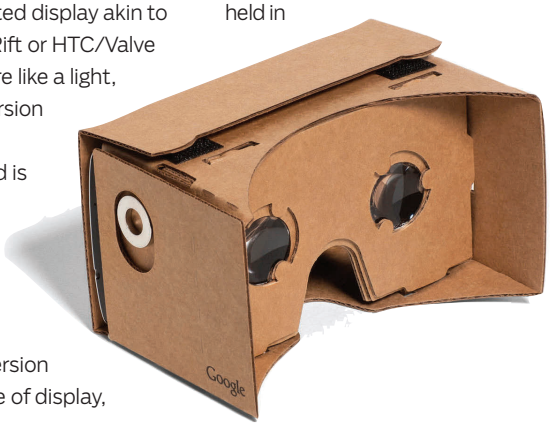
FROM: Google Developers
SHIPPING: Now
PRICE: Free

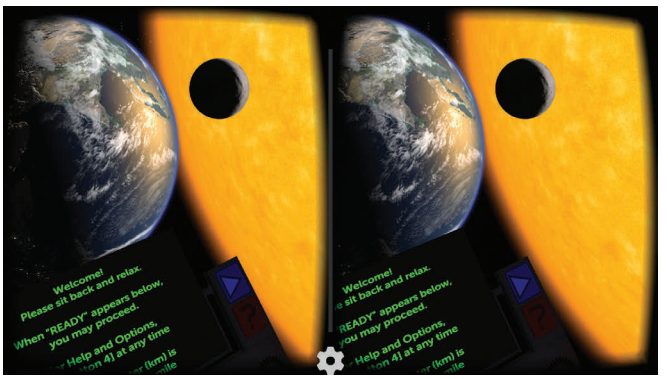
Google Cardboard has brought mobile virtual reality to the masses like no other device, and began doing so well over a year ago. Let's be clear, this is not a head-mounted display akin to the Oculus Rift or HTC/Valve Vive. It's more like a light, very light, version of an HMD.

Cardboard is made of, well, cardboard. It looks like an early prototype version of some type of display, but it works. And it's very inexpensive – there are many versions offered on Amazon (there is no official manufacturer) ranging from $10 to $20, or for the more ambitious, there are DIY kits.

In fact, the headset was designed by Google, and the company offers the list of parts, schematics, and assembly instructions free on its website. The parts include cardboard cut to a specific shape, 45mm focal-length lenses, magnets or capacitive tape, a hook and loop fastener, a rubber band, and an optional near-field communications (NFC) tag.

A smartphone is then inserted into the back of the device and held in





***TITANS OF SPACE* IS AVAILABLE FOR GOOGLE CARDBOARD USERS.**

place by the fastener. A Google Cardboard-compatible app splits the smartphone display image into two images – one for each eye – and applies a barrel distortion to each image, causing images to be spherised. And, *voila*, a stereoscopic image with a wide field of view.

Google provides two SDKs for developing Cardboard applications – for Android and the Unity game engine. Both use OpenGL. Third-party apps are available on the Google Play store and App Store for iOS.

GEAR VR

FROM: Samsung
SHIPPING: Now
PRICE: $99

Samsung's Gear VR was fast out of the gate, bringing portable virtual reality to users across the globe. The new Gear VR, which began shipping in November, is lighter than the earlier Innovator Edition (it is 318 grams without the attached phone) and sports improved ergonomics and a redesigned touchpad for easier navigation.

Unlike many VR head-mounted displays, Gear VR utilizes Samsung smartphones to display and process the content. It currently works with the Galaxy Note 5, Galaxy S6 edge+, S6, and S6 edge phones. A user just has to slip the phone into the front pocket and is ready to explore, untethered. Another advantage to this unique design: Users almost always have their smartphones with them, and the HMD is portable enough to place inside a backpack or pocketbook, making it always readily accessible. This will become an important feature as VR-supported content becomes widely available in our world.

However powerful these smartphones are, they are not nearly as robust as a souped-up PC or PS4. So, the viewing experience with Gear VR will not be as robust compared to those other devices. But for the price, the portability, and the fact that this is available now, it's a fantastic deal, especially if you already have a compatible Galaxy phone.

Gear VR contains a "super AMOLED" display (2560x1440), a 60 HZ refresh rate, precise head tracking, and low latency. The device offers a 96-degree field of view, which is less than the Oculus Rift and Sony PSVR. The device also has a custom IMU (inertial measurement unit) using accelerometers, gyrometers, and a proximity sensor for rotational tracking that connects to the smartphone via mico-USB. Motion sensors in the phone track the user's head movements, so this capability is more limiting than what is offered in some of the other HMDs.

Pixel density, however, depends on the phone being used: The smaller devices, such as the 5.1-inch Galaxy S6 and S6 Edge Plus, have screens with a greater pixel density than the larger phones (557 pixels per inch versus 518), offering a crisper VR image. A focus wheel on the top of the headset enables the user to adjust the image focus.

A touchpad – shaped like a game controller – on the right side of the device serves as the primary controller. For a more traditional approach, the Bluetooth SteelSeries Stratus XL for Windows and Android gamepad, which is sold separately, can be used for navigating content.

Here's the surprise: Gear VR is powered by Oculus. What does that mean? Oculus helped Samsung build the device. So once your phone is docked, the Oculus app will launch, and you, in turn, will be launched into a virtual world. From there, you can select apps and games from the Oculus menu.

A number of games and experiences are available for Gear VR, and many are coming soon, including *Land's End* (Ustwo Games), *Bandit Six: Salvo* (Climax Studios), and *Dead Secret* (Robot Invader). And since the Samsung Gear VR is powered by Oculus, content – lots of content – is available.

The Oculus Arcade includes 20 classic games such as *Pacman, Sonic the Hedgehog,* and *Gauntlet*. Through Oculus Video, users can access more than 9,000 videos from Vimeo or watch live broadcasts on Twitch. Also available is the entire Netflix catalog of original series, documentaries, and films. At Oculus 360 Photos, more than 200,000 immersive photographs can be explored. Lastly, with Oculus Social, users can select an avatar and hang out with other users in a virtual space.

If you want audio, however, you will need to purchase a good set of Bluetooth headphones.

***BANDIT SIX: SALVO* IS ONE TITLE THAT CAN BE PLAYED ON GEAR VR.**

OCULUS RIFT

FROM: Facebook
SHIPPING: Q1 2016 (pre-orders shipping March 28, 2016)
PRICE: $599 (pre-order)

This is what started the new revolution in VR, thanks to Inventor Palmer Luckey. The Rift began as a Kickstarter

campaign in mid-2012, with then-developer Oculus VR raising $2.5 million for the PC-based VR headset. Details on this game-changing device have been kept close to the vest, with information finally trickling out the hour pre-orders began on January 6, 2016.

A great deal of attention went into the Rift's design in terms of ergonomics and aesthetics. It is thickly padded and fits easily and comfortably on the head, with attached earphones (licensed RealSpace 3D Audio technology from VisiSonics) that emit high-quality 3D sound for an immersive experience. The lenses are easily adjustable to accommodate a variety of pupil distances.

While comfort is important, the biggest factor to consider is the display technology and tracking. To this end, this device has two integrated OLED (organic light-emitting diode) displays with a combined resolution of 2160x1200 (1080x1200 per eye), 90 HZ global refresh rate, and a "wide field of view" (approximated at 110 degrees). The high refresh rate, the global refresh, and the use of low persistence (displaying each frame of an image for 2 msec) eliminates motion blur.

The head tracking provides precise, low-latency, sub-millimeter-accurate 6 degrees of freedom (DOF) via the Oculus Constellation tracking system: three-axis rotational tracking and three-axis positional tracking. The latter is achieved with a USB stationary IR sensor. This enables the device to be used while sitting, standing, or moving around the same room where the sensor is located.

The Oculus Rift is not a stand-alone device: It connects to a PC running Microsoft Windows, with support for OS X and Linux said to be in the future. Experts advise equipping the computer with a high-end graphics card (equivalent to an Nvidia GeForce GTX 970 or AMD R9 290) and a substantial CPU (Intel i5-4590 or better). Oculus is partnering with PC manufacturers (such as Dell, Asus, and Alienware) for soon-to-be-released machines optimized for the Rift, priced at approximately $1,000. Or, consumers can pre-order an Oculus-ready PC and headset bundle for about $1,500 starting in February.

Oculus development kits have been available, the first (D1) in 2012 and another (D2) in mid-2014, so that at launch, close to a dozen titles would be available. CCP's *Eve: Valkyrie* (a multi-person space shooter) and Playful's *Lucky's Tale* (a colorful adventure title) are two very different types of games included with all Rift pre-orders. In all likelihood to promote content for the device, the company revealed that it was fully funding more than 20 second-party titles exclusively for the Rift, including Insomniac's *Edge of Nowhere*, and by year-end, expects availability of 100-plus offerings.

The free Oculus PC SDK for Windows enabled developers to tackle the finer aspects of VR content, such as optical distortion and advanced rendering requirements. The SDK also has been integrated into popular game engines such as Unity 5, Epic's Unreal Engine 4, and Crytek's CryEngine.

The Rift ships with an Xbox One Wireless Gamepad, to accommodate most of the games that have been developed thus far. To expand the immersive experience, the company is working on Oculus Touch, wireless handheld controllers for enabling hand movement and gestures in virtual space. The controllers are tracked through the Oculus Constellation system in 3D space, enabling users to manipulate objects with precision.

Additionally, Oculus is offering Medium, its creation platform (think virtual clay) for natural sculpting.

Users can select content from the Oculus Home environment, where they can launch VR applications, purchase apps from the Oculus Home store, or connect with friends also using the Rift. To keep latency low, applications output directly to the Rift, bypassing the PC's operating system. This is done through custom Oculus drives and a runtime service, both of which are needed in order to use the Rift.

A free application included with the Rift is Oculus Cinema, where users can watch conventional movies and videos from inside a virtual cinema environment. A networking feature enables multiple users to watch the same video in the same space, interacting with one another as avatars. Users can also watch 360-degree 3D (spherical) video and VR movies as they become available.

***LUCKY'S TALE* WILL BE INCLUDED WITH PRE-ORDERS OF THE RIFT.**

HTC VIVE

FROM: HTC (and Valve)
SHIPPING: April 2016 (pre-orders start Feb. 29)
PRICE: Unknown

The HTC Vive is a joint offering from two very different companies: HTC, known for its phones, and Valve, a gaming company well versed in the development and distribution of digital content. So, it would seem logical that the Vive would be similar to the Samsung Gear VR in that the HMD would utilize a smartphone. But that is not the case.

***FINAL APPROACH* (TOP) AND *ARIZONA SUNSHINE* (BOTTOM) WILL BE READY TO USE WITH THE HTC VIVE.**

The Vive needs to be wired to a PC, like the Oculus Rift.

Perhaps this sheds some light on the subject. The Vive is part of Valve's SteamVR virtual-reality system. Valve is building the tools and plans to partner up with multiple hardware companies for the SteamVR headset. The first such hardware provider (and seemingly the only thus far) is HTC, which is providing the Vive headset that will be powered via SteamVR.

Pricing initially was "guesstimated" in the $600 range, but reports just days after Facebook revealed Oculus's $599 tag have Vive costing anywhere from $200 to $600. But it's all speculation at this point.

While details are still incomplete, the Vive promises high-quality graphics, video that plays at 90 fps, and impressive audio fidelity. In fact, comparisons show that its display (OLED), resolution (2160x1200), and refresh rate (90 Hz) are the same as the Rift. This is also true for the field of view (110 degrees) and connections (HDMI, USB 2.0, USB 3.0).

The differences are with the platform. For the Vive, this will be SteamVR, Valve's storefront for VR applications and experiences. Additional content from partners such as HBO is also expected.

The Vive touts a pair of SteamVR controllers for exploring virtual environments and for use as game controllers; the SteamVR controllers function similar to a modified Steam Controller. The Vive also supports a PC-compatible gamepad.

The Vive uses laser positioning and more than 70 sensors, including a gyroscope and accelerometer. It also has a front-facing camera that integrates directly with the so-called Chaperone system for the Room Scale Experience that lets users walk around a room that's up to 15x15 feet.

This feature employs sensor boxes to identify the perimeter and objects in the space; a grid outline of the room is projected when the user gets too close to these barriers. In a nutshell, it merges the real world with the virtual world (but do not mistake this for AR). Plus, it offers unmatched freedom of movement in VR space (but it is still limited by the cable that attaches the HMD to the PC).

The headset itself has many laser sensors that receive data from two Base Stations attached to two walls of the room where it is used.

At CES in January, the company was showing off the Vive Pre, the latest version of the hardware. Initially, the Vive was to ship at the end of 2015, but that was delayed due to some design changes, including the addition of the front-facing camera (which no doubt will affect the price of the device). Other tweaks are expected before the HMD hits shelves, as HTC and Valve have stated that the Pre developer's unit will be followed by another, final version.

PLAYSTATION VR

FROM: Sony
SHIPPING: 2016 (estimated first half of the year)
PRICE: Unknown

It was known as Project Morpheus but more recently has been identified as PlayStation VR (PSVR). Whatever you call it, the device is a major competitor to Oculus Rift in that comparisons are continually being made between the two HMDs.

As of press time, pricing for PlayStation VR was still unknown, and whether Sony will take note of the disgruntled community's reaction January 6 after Facebook unveiled the $599 price tag for the Rift is anyone's guess at this point. Early speculation points to $800 to $1,200.

PSVR, like Rift, will sport a 5.7-inch OLED display. It will have a combined resolution of 1920x1080, or 960x1080 per eye, which is less than Rift and Vive. Its refresh rate is touted at 90 Hz (like Rift), although it can render games at up to 120 Hz. Furthermore, PSVR is said to have a vertical field of view of approximately 100 degrees, slightly narrower than the Rift's.

Similar to the Rift, PSVR contains an accelerometer and gyroscope, but whereas the Rift contains the Oculus Constellation tracking system, the PSVR will use the PlayStation Eye tracking system (an approximate $50 add-on). And yes, it also has 3D audio with built-in speakers. As for input, a PlayStation Move and Dual Shock 4 controller are needed.

While the Rift is being positioned as a consumer VR headset for games and much more, PlayStation's entry to the market will be used for the PlayStation 4 gaming console, which currently costs $350.

Whether it will also work with other applications and platforms is unknown. Alas, the Rift requires a souped-up PC – a major beef with users, but it will offer a more powerful platform than the console. Will the PSVR work out of the box with the PS4, or will a special upgrade be required? That has yet to be answered.

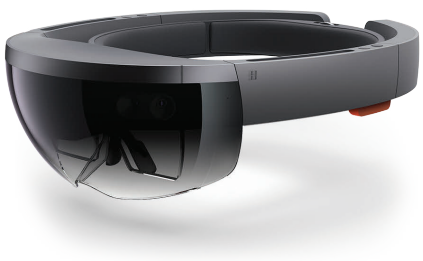
Everything anyone seems to know about the PSVR comes from what we have

seen on paper, as no review units have been distributed. The big question, other than pricing, is when will the device ship? So far, the only indication is sometime this year, with a hint that it would be in the first half. However, we have heard projected dates for many of these HMDs already, only to be informed of a delay, so we'll have to wait and see.

HOLOLENS

FROM: Microsoft
SHIPPING: Q1 2016 (Development Edition)
PRICE: $3,000 (development kit)

Microsoft's HoloLens is a different animal from many of the other head-mounted displays shipping now or about to ship. It's an augmented-reality device, superimposing virtual text, images, and objects onto a person's real-world field of vision. As such, it does not obscure a person's entire view. So, the wearers can use their hands for input and selection.



The device is more of a combination headband/glasses/visor – in essence, a smart glasses headset – covered in cameras for head tracking. Essentially, it is a self-contained Windows 10 computer that fits on a person's head. And while HMDs like the Rift and Vive have high-res displays that fill a user's field of view, the projected images from the HoloLens are much smaller.

While it is reasonable to expect that the HoloLens will be used for gaming (considering Microsoft's ownership of the popular Xbox console and cadre of game development facilities under its Microsoft Studios), at this time the company is touting more business-level capabilities in the areas of product design and development, medical applications, engineering, and the like.

Microsoft is calling the HoloLens the first holographic computer, integrating HD images with the real world via Windows 10. The device comprises an optical system that works in conjunction with advanced sensors. Transparent Holographic HD lenses use an advanced optical projection system, generating multi-dimensional, full-color images with very low latency.

A custom holographic processing unit (HPU) from Microsoft analyzes and integrates data from the sensors for tasks such as spatial mapping, gesture recognition, and voice and speech recognition. While it crunches a large amount of data (terabytes of information) from the sensors, this occurs in real time.

Most of the sensors are in the front of the headband, as is the related hardware, such as depth sensors, photo/video camera, and HPU. The HoloLens also contains a set of small stereo speakers, enabling the wearer to hear virtual sounds as well as real-world sounds.

Like the usual HMDs, the HoloLens sports an inertial measurement unit comprising an accelerometer, gyroscope, and magnetometer. There are three layers of lenses (blue, green, and red), each with diffractive features.

No wires, PC connection, phone, or external cameras are needed, so users are free (untethered) to explore their environment. HoloLens understands gestures and the direction the user looks, and maps the world around the person in real time.

Currently, the HoloLens is available only for developers – and by invitation only.

THE HOLOLENS IS A SELF-CONTAINED WINDOWS 10 COMPUTER.

THE TIP OF THE ICEBERG

The race to fill the VR HMD space has been progressing at a frenzied pace for more than a year. While some deadlines came and went, we definitely appear to be on the verge of a new era that will surely bring VR to the masses, particularly the gaming masses.

There are a number of other companies than those mentioned in this article that are poised to make a play for this market. PC maker Asus is talking to Microsoft about a HoloLens version of its own. Later in the year, Razer plans an OSVR Hacker Dev Kit that can be paired with a phone or PC for build-it-yourselfers. Those are but a few additional offerings we can expect in the next 12 months or so as VR and AR content become more prevalent and whet our appetite for exciting new experiences. ■

Karen Moltenbrey is the chief editor of *Computer Graphics World.*

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A FAMILY AFFAIR

A PRACTICED CREW AT DREAMWORKS ANIMATION PUSHES CG BOUNDARIES TO CREATE THE THIRD *KUNG FU PANDA* FILM

BY BARBARA ROBERTSON

In the universe of CG animated films, the beautifully designed *Kung Fu Panda* series stands out for its unique graphic visual language, colorful animated action, humor, and one of the most improbable heroes ever to star in a major motion picture.

Po (Jack Black), the remarkably clumsy, irrepressible, and overweight giant panda, has proven to be the Dragon Warrior he imagined during the first two films in the series. But, even though he defeated a villain in each, he remained lovably insecure and vulnerable. In *Kung Fu Panda 3,* the Dragon Warrior must now defeat the most frightening villain yet, a supernatural beast called Kai (JK Simmons). To do so, the warrior must become a teacher. But, can the self-doubting sometime hero convince himself he's good enough to teach?

Directed by Jennifer Yuh Nelson and Alessandro Carloni, the story takes place largely in two worlds: a dangerous, dramatic spirit realm inhabited by Kai, and a charming, bucolic panda village. In this film, Po meets his biological father, Li Shan (Bryan Cranston), an older version of himself without the discipline of martial arts training. Li Shan leads him to the secret panda village high in the mountains.

Created at DreamWorks Animation in Glendale, California, and Oriental DreamWorks in Shanghai, China, *Kung Fu Panda 3* again pays tribute to wuxia, a genre of Chinese fiction centered on martial artists in ancient China. But, *Kung Fu Panda*'s martial arts practitioners are animals. Indeed, animals make up the entire population.

Even though it has been eight years since the first film, *Kung Fu Panda*, and five years since *Kung Fu Panda 2*, all the actors playing major roles returned for the third, as did much of the crew. Nelson had directed the Oscar-nominated second film and was head of story and director of the dream sequence for the Oscar-nominated first film. Carloni was animation supervisor and story artist on the first film, and a story artist on the second. Melissa Cobb produced all three.

"Most of the crew has stayed together for the past 10 years," Cobb says. "We know the world, and we know the style. Also, among ourselves we have good communication and trust. We're a family, one with mutual respect. So we were able to get a lot more done; we could push the boundaries."

PO AND HIS LOOK-ALIKE BIOLOGICAL DAD SHARE THE SAME SENSE OF HUMOR.

One way in which the crew pushed the boundaries was in the look.

"There has been a big battle to make photorealistic animated films," Carloni says. "Finally, we've gotten past that and can just make films as beautiful as we can, even super stylized and graphic."

Previous films had graphic sequences – sometimes hand-drawn, sometimes 2D – but in *Kung Fu Panda 3*, that look moved into a 3D environment: the spirit realm.

"We've always had graphic images in the film," Nelson says. "We've used a 2D look to show what's in Po's head. But in this film, when Po's in the spirit realm, the graphic images from the first movie became that world. We remade the 2D look in 3D. It feels real not because of photorealism, but viscerally and emotionally real because it's so pushed. The colors are more saturated, the environment is more insane, the impact is bigger because of the visual language."

STORY DEVELOPMENT

Nelson and Carloni are both story artists, so both drew storyboards for the film.

"That's where we discover the story," Carloni says. "The story artists and the writers piggyback off each other. I think we probably board each sequence 20 times. We redo every moment, and each time we have to be completely original and do the best work we've ever done."

As they developed the characters, the action, and the environments, the directors had an advantage over those working on the previous films.

"On the first film, Raymond [Zibach, production designer] and Tang [Kheng Heng, art director] did so much research to get all the elements accurate," Nelson says. "On the second film, we photographed in China. This time, we could ask the studio in China what is accurate."

"They would draw things for us," Carloni adds. "If we needed calligraphy or poetry, they would do it or find it. When we made the first *Kung Fu Panda*, the people in China liked it. They asked if we could make one together, and it made complete sense for this movie. We're making a movie about their culture."

Although set in China, the film's themes are universal. "Po's journey is always about self-discovery, about maintaining who he is," Nelson says. "Now, he takes another step. It's just harder. The student becomes the teacher. So many kung fu movies have a student in front of other students. This is Po's version."

Po's journey into self-discovery is facilitated by the surprise appearance of his biological father. When Po and his dad meet, they don't recognize each other at first. As they turn away from each other, a crowd of bunnies and pigs stare in amazement. The scene is one of Nelson's favorites.

"It's a gag that the animators figured out," Nelson says. "A simple and logical idea that would happen only with these two characters."

"When we pitched the idea, some people said they [Po and his dad] looked stupid," Carloni says. "We said, 'Trust us. It will be so funny.' Everyone laughs during the close-up crowd shot. That was Jeffrey's [Katzenberg, DreamWorks' CEO] idea. He told us we had to have the cutback to the crowd."

PREMO ANIMATION

To create that gag and all the characters' performances,

EFFECTIVE TOOLS

"Looking back," says Visual Effects Supervisor Mark Edwards, "this was a pretty big effects movie. We had snow, rain, splashes, destruction, blowing sand, dust, waterfalls, and petals, lots of petals. I think we pushed the state of the art in a few areas. The jade palace destruction, for instance. The number of assets is the highest we've had at the studio, and we had massive amounts of rigid-body destruction. Especially close-up. We had a bazillion scrolls. Debris. We had so many materials – paper, stone, wood. Our sims showed flexing and splintering."

The effects department has based many of its tools on Side Effects' Houdini. Flux, a fast, hybrid gas solver with options for combustion, handles various volumes with a tight integration into Houdini via SOP nodes. The artists used Flux for smoke, fire, clouds, dust, and so forth. An internal solver called Rapid, also integrated into Houdini, simulates liquids.

Character effects artists relied on the FXGear Qualoth plug-in for Maya for cloth simulations. Two proprietary hair and fur set-up and grooming systems, Fur and Willow, provided guide hairs for Houdini-based simulations.

"We optimized our Fur caching to handle lots of pandas and the grass in panda village," Edwards says. "[R&D Engineer] Feng Xie helped us devise a way to cache out a lot of data at one time. It was a huge optimization."

For lighting, the team uses a proprietary tool called Torch; for rendering, the studio's own point-based global illumination (PBGI) system called Moonlight.

"We developed a way to trace shadows with PBGI data, updated the renderer to deal with AOVs (arbitrary output variables), and pushed out some fixes to do deep compositing in [The Foundry's] Nuke," Edwards says. "Also, for certain things, we used [Side Effects'] Mantra. With our graphic look, it was imperative to push the color, so we did a lot of work in Nuke to keep the saturation."

A small team working in Adobe After Effects handled the integration of elements into the 2D scrolls, and the inky stylized credit at the end.

"When you see the 2D scroll in stereo, it looks really cool because of the After Effects elements, even though it's flat," Edwards says.

the animation team used Premo, DreamWorks' new in-house animation system.

"Animators can now touch the sculpture that is a panda and truly interact with the model itself," Carloni says.

Supervising Animator Jason Reisig explains that although he can use a mouse and keyboard shortcuts, he doesn't need either. Instead, he performs a character using Wacom's Cintiq tablet.

"I want to touch something and move it," Reisig says. "I can pose right on the character. Move him around, grab the corners of his mouth, change expressions, move an arm. I can do this mirrored or not. The process is very tactile. It feels like working with a stop-frame puppet, but I'm posing at nearly 24 frames per second."

Reisig was a member of the advisory board that helped develop Premo.

"We first began talking about this six or seven years ago, and tried to determine what would be most important," Reisig says. "We gathered a ton of information and guidelines for early development. The top 10 requests were about speed and the fidelity of the characters, about interacting with characters in real time in high resolution. We knew R&D would have to build tools from scratch, and we couldn't do everything at once."

R&D had Premo ready for animators on *How to Train Your Dragon,* and feedback from that production influenced the next generation. Animators on *Kung Fu Panda 3* were especially excited about Premo's new shot browser.

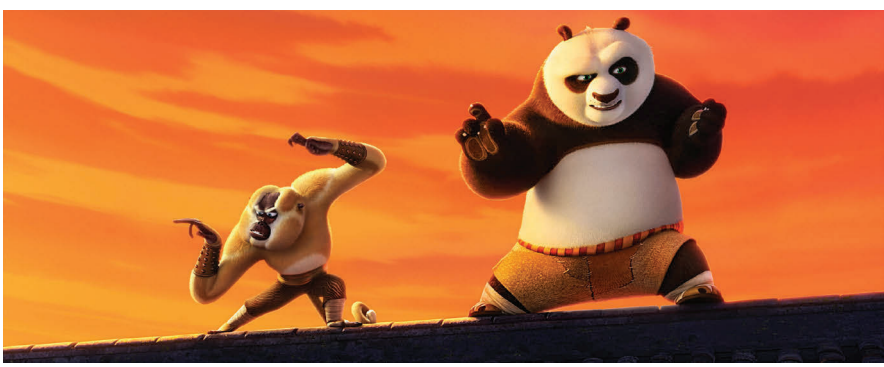
"Historically, we would open a shot, load assets, work on it, save it, close it, open a new shot, load assets, and so forth," says Supervising Animator Ludovic Bouancheau. "If I wanted to copy and paste across shots, I'd have to go to one shot, copy, close it, then open another shot. I'd be doing that blindly. Now, we have an open pipeline to multiple shots. Premo looks at all the assets and loads everything. So, we can access all the shots in a sequence at the same time. I can look at an entire sequence and draw on it, and I can copy and paste across shots."

Although animators are "in" only one shot (that is, one file) at a time, the rest of the sequence is available and viewable in a shot browser on-screen with the shots' current stage of production – whether storyboard, layout, final, or something in between. Animators can scrub through a sequence and instantly switch from the shot they are working on to another. They can't override another person's work, but they can see it.

"We can choose categories that we want in our browser," Bouancheau says. "I can choose which layout version – previs, rough, or final layout. I can look at three types of rendering. At effects, character effects, lighting. I can add categories. On *Panda,* we were doing a lot of 2D animation for fighting choreography, so I could play that animation in the shot to reference it."

This ability to view an entire sequence had an impact beyond an individual animators' ability to work on shots.

"It changed how we cast and run the department," Reisig says. "Now, animators handle groups of shots, not one here and there. They can go from one shot with a lot of characters



ARTISTS OFTEN RELIED ON MATTE PAINTINGS FOR A COLORFUL GRAPHIC STYLE.

THE VILLAIN KAI LIVES IN A HIGHLY STYLIZED SPIRIT REALM.

to another in real time and work across edits. They have continuity. What's special about Premo is that it says, 'I understand the sequence you're in. I know the other movie files you want.' And, it gives them to you without you having to search them out. It understands the broader scope of what we're doing."

The ability to quickly view and work with shots for an entire sequence also changed how supervisors worked with animators on their teams.

"I can look at an entire sequence and draw on it," Bouancheau says. "I have tools like [Adobe's] Photoshop, so I can paint to change shapes. Being able to stay in the environment has made a huge difference for my own work and for communicating with animators. The animators can load a layer with my name on it and view it. They can load drawings by the person who drew them, by notes, by poses, whatever. They don't have to load only one particular shot."

The impact of Premo and its underlying platform Apollo also extends beyond animation.

BEYOND PREMO

"We think of Apollo as a platform, not a pipeline," says Kate Swanborg, head of technology communications and strategic alliances. "Apollo is cloud-based. It has all the assets, all the applications whether proprietary or third party. Apollo is ours. Premo is ours. The pipeline is the workflow that connects applications and assets into the platform."

Thus, via Apollo, Premo's shot browser could become available to other departments.

"When the other departments saw it, it went to the top of everyone's list," Swanborg says. "It's where all the artists want to head, so it's about to be part of other tools as well."

Already, some tools have been updated with the shot browser in mind.

"We really optimized Tiber, our layout tool set, for the sequence-based workflow and sequence-based changes," says VFX Supervisor Mark Edwards.

This was particularly important for sequences set in the panda village.

"People working on the sequence could see all the shots around them," explains Swanborg. "If we had tried to do this before, we might have made choices that scaled the village down, rather than the choices the filmmakers made now."

SECRET VILLAGE, SPIRIT REALM

Po's father, Li Shan, takes the Dragon Warrior to the secret panda village to find his chi, which will help Po defeat the villain Kai. Po follows his father up a steep mountain, past waterfalls, into a curtain of mist.

"We couldn't see the mist until the last render," Carloni says. "People would say to us, 'The shot isn't grand.' And I would tell them, "Yes, because we don't have the reveal.'"

When the mist lifts, we see the grand secret – a brilliantly colored village populated with excited pandas large and small, young and old.

"That shot was tricky because it was a cross-departmental effect," Edwards says. "Lighting, effects, matte painting all came together in the final comp. We knew what we needed, but it definitely took iterations to get just the right look."

The sets department built the entire village, not just spots needed for particular shots.

"We needed the panda village to feel super special, livably lush, but high in the mountains," Edwards says. "We designed huts for all the major players. There's a festive community cooking area – pandas eat a lot. We have rolling slopes, grassy areas, bamboo, and waterfalls to make it feel more magical. Because half the film takes place there and we knew the story would take us all over the village, we built high-resolution sets for all the main areas, and low resolution outside."

The second major set piece, the spirit realm, provides the location for much of the action sequences in the film. Kai lives here.

"Kai brought chaos to this

JOMBIES

When the villain Kai wields his jade blades to steal chi from the kung fu masters, we see a gigantic explosion of energy. The questions the effects team had to answer were, what do liquid jade and the transformed characters look like?

"We had lots of concepts," says Visual Effects Supervisor Mark Edwards. "One had them looking like Egyptian mummies."

Executive Producer Guillermo del Toro came up with the idea of referencing the carved jade amulets often seen in China.

"We ran some tests and discovered that when the jade was translucent, it looked cool," Edwards says.

The transformed characters look like jade sculptures. Particles helped with the transition.

"We used a pretty straightforward particle trail and a blend of particle passes to push them into the shape of the geometry. Then, we had a lot of compositing to hide pieces of the transformations and make sure the blend worked with the glow."

DUMPLINGS

One way in which Po tries to defeat Kai is by enlisting the help of the pandas in the village, including an "army" of adorable pandas affectionately known as the "Dumpling Squadron."

"Our village had a small population, but it needed to feel like a full village with 30-some pandas, all pretty unique," says Visual Effects Supervisor Mark Edwards. "Our head of crowds developed a system to easily move to and from Premo. The animators could use cycles for the crowd characters, and if they needed to push the performance further, they could animate them in Premo."

"In the finale, we had hundreds of characters – all the panda villagers, all the valley of peace piglets, rabbits, and geese," Edwards adds. "It was our biggest crowd sequence. So, we used Massive for that. We can move Premo cycles into Massive, and we can take a Massive character and move it into Premo."

space," Edwards says. "In the opening shot, if you look at it from the right angle, you can see that the classic yin yang symbol forms part of the design. But other pieces feel fractured and chaotic. Even so, we wanted some kind of structural elements. Part of a building attached to a rock. Oogway's tree. A lot of this work was done at Oriental DreamWorks. I pushed for a true geometric representation of everything. We also had matte paintings everywhere to stylize and push the look. We'd use projections. We had locked-off shots. We used whatever made sense."

Within the spirit realm, the sets team had three phases: the opening sequence, Po's return, and Po's empowerment.

"Once Po is empowered by panda chi, we built a new set with the big palace as a backdrop and columns designed to provide structure. The floor had cloud shapes. And then we transformed it again for a calm, golden realm."

The artists created the imagery from concept art painted by Art Director Max Boas.

"His painting of all the petals with the [golden] chi color was so beautiful, I literally took the painting down and boarded a chicken-scratch drawing," Nelson says. "I told the artists to use this painting for this shot. This composition, those lights, those colors. That's why it is so pushed."

It is a perfect example of what sets this franchise apart from other animated films. With *Kung Fu Panda 3,* the studio has taken a visual language and animation style that worked for the first two films, added advances in technology over the past 10 years, and created a new work that showcases the self-discovery of all the artists at the studio. ■

BUNNIES

On *Kung Fu Panda*, Producer Melissa Cobb voiced the bunny mom. On this film, her daughter voiced one of the little bunnies. One of the editors' sons has a voice, as does Dustin Hoffman's grandson and the children of other actors.

"Near the start of the film, the bunny that says, 'Go Dragon,' to Po (actor Jack Black) is Jack Black's son," says Director Alessandro Carloni.

It's only right that some children born during the 10 years of production on the three films had roles on this one. "Four of Angelina Jolie's kids voice characters in the film," Cobb says. "She was pregnant with the twins when we premiered *Kung Fu Panda* in Cannes. In a sense, we all feel like family."

Barbara Robertson (BarbaraRR@comcast.net) is an award-winning writer and a contributing editor for *CGW.*

SHOWN HERE ARE PO, HIS FATHER, AND THE FURIOUS FIVE WARRIORS, MANY OF WHOM WOULD BECOME JOMBIES DURING THE FILM.

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PICTURE Perfect

COMPLEX CG SETS TRANSPORT FILM AUDIENCES TO UNIQUE LOCATIONS

More often than not, visual effects are big, bold, and in your face. However, not all VFX fall into that category, and yet they still elevate the story in dramatic ways.

Consider a handful of films released in the last quarter of 2015: *In the Heart of the Sea, The Walk, Bridge of Spies, Everest*, and *The Martian*, to name a few. All five movies feature digitally constructed environments that were vital to the story line. Four – *In the Heart of the Sea, The Walk, Everest*, and *Bridge of Spies* – required an accurate re-creation of a real-life period locale. The Cold War era backdrop for *Bridge of Spies.* The harsh watery landscape battering the 1820s vessel "Essex" in *The Heart of the Sea*. The frigid landscape of Mount Everest during the ill-fated March 1996 trek. And, the heart-thumping void atop the 1974 World Trade Towers. *The Martian,* meanwhile, provided a barren backdrop of desolation based on scientific data mixed with artistry.

These environments set the tone for the respective films, transporting audiences to unique locations where they, too, could experience the drama, fear, isolation, and anxiety of the main characters.

Here, *CGW* reaches high and deep, looking at the amazing work that placed us on a thin wire atop the Twin Towers of the World Trade Center and on an 1820s whaling ship in the South Pacific. Online, *CGW* transports you behind the Berlin Wall during the Cold War, atop the highest mountain in the world, and to the bleak surface of Mars, to finish this digital journey.

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HIGHWATER MARK

EFFECTS ARTISTS BATTLE ROUGH SEAS FOR THE FILM *IN THE HEART OF THE SEA*

BY KAREN MOLTENBREY

In the Heart of the Sea is a literal whale of a tale.

The story is inspired by the 1851 classic novel "Moby-Dick" by Herman Melville, which recounts the obsessive quest of a sea captain hell-bent on revenge after losing his leg in a previous struggle with a huge white whale. The movie, though, is based on the 2000 non-fiction book *In the Heart of the Sea: The Tragedy of the Whaleship Essex* by Nathaniel Philbrick, about the sinking of the "Essex" by a vengeful mammoth white whale that turns the tables so the hunters become the hunted, and proceeds to stalk the survivors during the ill-fated voyage. This is the true life-and-death struggle recounted by survivors that formed the basis for Melville's book many decades ago.

The movie's drama, naturally, takes place on the high seas. A good deal of *Sea* was filmed practically, offshore in the Canary Islands and at Warner Bros. Studios Leavesden in the UK. According to Double Negative's David Hyde, effects supervisor for *Sea*, filmmakers sailed a tall ship similar to "Essex" to the Canary Islands, enabling the visual effects department to shoot oceanscape plates from the deck en route that they later augmented with CG for panoramic seagoing scenes.

At Leavesden, meanwhile, an exterior bluescreen was constructed for the harbor shots at Nantucket's port, along with an "Essex" deck atop a hydraulic gimbal system used to mimic the pitch of the stormy seas. An interior water tank was constructed from shipping containers to house the smaller whaling boat rigs, also on a hydraulic puppetry system.

The hydraulic rig was used to shoot close-ups of the so-called Nantucket sleigh rides – when the smaller whaling boats launched during a hunt were subsequently dragged across the water by a harpooned whale.

"A substantial amount of the water was caught on film, which was very good for us," says Hyde, noting that in some cases the practical water was then augmented with CG, while in others it was all-digital.

"When we had a whale breaching or a dolphin breaking the surface, we would have to simulate that," says Hyde. "And sometimes, particularly when using the interior tank, we would have to replace the water around the whale boats, to make them look like they were traveling at 17 to 20 knots while being dragged by a harpooned whale."

There were four main areas when CG water was required: for

large seascapes that were not caught on film, for depicting boat and whale/dolphin interaction, for underwater effects, and for augmentation, such as white water to make the sea look choppier and for expelling water through the blow hole of the whales – creatures that are also computer-generated (see "Whale of a Character," page 34).

MAKING WAVES

Generating the various types of water was done using Side Effects Software's Houdini as well as DNeg's in-house water simulation solver, Dynamo. Both are so-called FLIP solvers, a hybrid between a particle-based and a volume-based fluid simulation.

"We were fully aware from the start that the turnaround times for complex simulations would be a big hurdle. And final animation could not be approved until we could review how the animation and FX interacted with each other," says Hyde. "Even with the talented FX crew we had, the fact of the matter is these simulations can take many hours. It's a slow process."

Of the 30-so effects artists on the feature, nearly three-quarters of them worked on the water creation.

The effects leads – Robert Pearson, Chris Ung, and Menno Dijkstra – were constantly developing tools and techniques through production to streamline the sim process. "If you can save a couple of seconds per frame of simulation, on a 200-frame shot where you do the sim a number of times and then across a production with many shots, that time-savings can be substantial."

The group used *Sea* to push the studio's Dynamo in-house solver forward with new features. "We picked a number of shots we said we would push through the software, and it was quite successful. We would jump back to Houdini if we sensed we could get better results, and vice versa – there were certain features in Dynamo that were better for certain shots," says Hyde. "This gave us more than one option and the freedom to try different things."

Of course, having an in-house R&D team working on a piece of software has lots of advantages, and many of those involved changes that resulted in the important fast turnarounds.

While Dynamo proved its mettle, Houdini was the main

THE MOVIE CALLED FOR A RANGE OF WATER REQUIREMENTS, FROM CLOSE-UP TO WIDE SHOTS.

solver used. In fact, the decision was made early on to run the majority of the production's pipeline through Houdini, with the reasoning that everything was so tightly coupled together – from postvis, to effects, to lighting. Rendering was done in Mantra for the most part, with the "Essex" destruction sequence rendered in Maya with Pixar's RenderMan. "Keeping everything within one package was the ideal route because it meant everyone was working off the same platform, and it proved successful," says Hyde. "We were able to develop a very streamlined pipeline by staying with Houdini."

One of the main challenges recognized early in the process was how to integrate the live action, animation, and effects simulations. Hyde explains: "A whale breaching or interacting with the surface, for example, would need a representation of the CG water surface for animators to realistically animate to. Likewise, with the action footage of the hydraulics, the water surface has to behave so it looks like it initiated the movement of the boats."

To this end, the group implemented a high-level postvisualization stage before proceeding to shot work.

"Here we generated proce-

WHALE OF A CHARACTER

DNeg artists chase their own white whale to create the antagonist for *In the Heart of the Sea*

For the feature film *In the Heart of the Sea,* the digital artists at Double Negative had to create a number of CG creatures: dolphins, remora fish, seagulls, eels, great white sharks, and a plethora of smaller fish. They also gave life to families of bull, cow, and calf sperm whales that appear in approximately 80 shots. Their "biggest" task of all, though, was to create the film's antagonist: the vengeful behemoth white whale that appears in just over 60 shots.

The peculiar behavior of this whale seems almost unbelievable, yet the heart of the *Sea* story line is indeed real, prompting the filmmakers and digital artists to research and analyze the behavior of sperm whales.

The whales, including the antagonist, were brought to life via CGI by the visual effects team, led by VFX Producer Leslie Lerman and VFX Supervisor Jody Johnson. "It was particularly challenging, with a creature of such immense size and power, to push the envelope without going over the edge, since we didn't want to pluck the audience out of this real world and take them into a fantasy realm," says Johnson. "Each time we conceptualized an action sequence that involved the main whale or any of the secondary whales, we sent it off to our experts and we'd discuss how plausible it was and what other behaviors they might suggest. It gave us a great spectrum from which to work."

PROCESSING THE WHALES

DNeg's Tosh Elliott modeled all the sperm whales in the film. While there was an abundance of available photography, anatomical drawings were few and far between. To help maintain realism, whale expert Dr. Luke Rendell provided feedback during the process. "For instance, we discovered that whales do not have binocular vision, so both eyeballs would not be visible when directly facing a whale," Elliott explains.

Elliott started with the sperm whales and built them to accurately reflect real whales. A great deal of concept art, however, was done for the main whale, which needed to be an older character, not a sea monster. According to Production Designer Mark Tildesley, it was important to ensure that this whale felt like a living presence in the film.

The modelers shared topology among the adult secondary whales. Only the calf and dead bull were different enough to warrant their own unique structure. Extra details, such as wrinkles on the tails, were added to the characters in Autodesk's Maya and Pixologic's ZBrush. "We decided against a full-blown muscle system for the whales because the amount of blubber surrounding the muscles obscured them," says Kieron Helsdon, CG supervisor at DNeg.

The final bull and cow models were a realistic 52 feet and 36 feet long, respectively, while the behemoth was a whopping 95 feet long, weighing approximately 80 tons, with a tail spanning 20 feet – nearly double the size of the other whales in the film.

Laetitia Gabrielli textured the whale family in The Foundry's Mari, using variants so the whales did not look the same. She also added the small remora fish attached to the whales, which provided scale to these ocean mammals.

BATTLE SCARS

The large whale, though, required more attention. Initially, the group tried a few images of white whales, and while they looked "fantastic," the pure white color also gave them an ethereal, calm presence – certainly not the look that was needed for this vengeful creature. Research, though, revealed that many older whales start to lose their skin, so the artists made the whale darker but with visible white in patches where the skin has flaked off.

"He is also scarred from previous battles with humans and other predators, so his appearance conveys the harshness of his history," adds Lerman.

The texture artists reviewed whale scarring reference and how they heal after skin damage. They also considered the size of the creature and that of a human so the scars would have the correct scale for a harpoon injury. "While creating the scars, we found reference of how they shed their skin, and we ended up having cloth simulations of floating skin, to add to the damaged skin textures," says Helsdon. "This also created some movement and interest underwater."

Lookdev Artists Chris King and David Mucci then developed various looks for the creature, depending if it was below water or breaching above the surface and needed a wet look. "We found that with the underwater environments, after we tested with raytraced

dural water surfaces rather than dynamically simulating them, and Artist Geoffrey Coppin matched the look to the various sea conditions caught on film for animation timing," Hyde says. "So when the whale comes up to breathe or the boat dips a certain way, we used these surfaces for pumping the waves into our dynamic water surface simulation."

Once timing was worked out on the procedural surfaces at this postvisualization stage, the team ran a low-level simulation, using this procedural surface to pump in the wave velocities, to get the same type of waves flowing through the simulation dynamically. If all behaved accordingly and the broad movement was approved, the effects artists kicked off a high-resolution simulation. Depending on the size of the area, the simulation could take a few days to calculate and generate a couple of terabytes of data.

"The turnaround times were quite lengthy when we got into the high-quality simulation settings," says Hyde.

Next, the effects artists used that dynamic patch of water the whale or boat would interact with, and they would add it back into the original procedural surface. As a result, the dynamic simulation would only be simu-

caustics generated with water simulations, we needed to develop a multi-layered caustic projection setup because we wanted art to direct the look of the caustics depending on the shot feedback, as opposed to using a totally physically correct approach," Helsdon says.

According to Robyn Luckham, animation supervisor at DNeg, achieving the correct buoyancy and scale of the whales in animation was very difficult, as it had such a major effect on the water simulations. "The speed of a tail slap, for example, could create supersonic drops of water," he says. To keep this in check, Luckham had to maintain a delicate balance between the emotional intent of the shot and the technical constraints.

Of course, each department faced their own white whale, so to speak. For animation, it was creating realistic behavior for the massive sizes of the underwater and surface pods, which were undocumented. For lighting, it was the close-ups of the huge whale. For effects, it was getting the detail and scale into the water simulations.

The work on *Sea* was indeed a large undertaking, requiring a team effort among departments. This was especially important due to the tight integration of the sims with modeling, animation, and more.

"Working with David Hyde, effects supervisor on the film, the VFX artists created height wedges with low-resolution water simulations, which could be fed back to the animators," says Luckham. "This helped us select the right balance of being able to see the whales and the realism of their movement before committing to a simulation that could take several days to solve."

And in the end, it was all about the realism in this movie. After all, *In the Heart of the Sea* is a real story, about a real event, a real creature, and a real struggle for survival. So re-creating that realism was paramount. "For [the great whale], it was about him being a character, not a monster. So we had a lot of discussions about how best to portray that with the limited options we had. After all, whales cannot smile," says Helsdon.

Karen Moltenbrey is the chief editor of *Computer Graphics World.*

ARTISTS USED HOUDINI AND DNEG'S PROPRIETARY DYNAMO SOLVERS FOR THE CG WATER IN THE FILM.

lating the area of interest around the object. "It was very efficient," says Hyde. "We were not doing large-scale simulations that we didn't really need when the procedural water representation was just as good."

DIFFICULTIES AT SEA

According to Hyde, there were four sequences involving "heavy" CG water simulations, and they all had different requirements – from wide, expansive shots to others extremely close-up, and some underwater. "That is something we hadn't faced before, having to accommodate such a variation of 'water' environments, but we were able to adapt and meet those shot requirements through tool and pipeline development. And it worked across most of the shots the majority of the time."

One sequence involves the initial whale hunt, when the "Essex" first comes across the large pod of whales. "The idea being the whaling crew had been at sea for months and didn't see anything, then suddenly they come across all these whales," he says. "We had to simulate many whales for this epic look."

Early on in production, the animators built multiple animation cycles for the whales so that the effects artists could build up a library of generic sims for placement in some scenes later on, such as this one.

Another challenging sequence involved the second whale hunt, when the leviathan first fully appears. "Big, wide shots with the whale charging out of the water at the 'Essex,' " says Hyde. "Here the challenge was having convincing scale to the water in simulation areas approximately 300 feet wide in-camera."

The third is the other extreme, occurring at the end sequence when First Mate Own Chase (Chris Hemsworth), in one of the small whaling boats, confronts the great beast. The actors – and the water – appear in close-up. "We needed detail from one or two feet off the top of the water," Hyde adds. Some of those sims were done over two or three days and generated 5TB to 10TB of simulation data each.

The movie also contains a number of underwater effects that had to be approached differently than the surface water. Effects Lead Tamar Chatterjee created an approach that enabled the group to do a localized fluid simulation around the object that would be underwater, such as the whale or dolphin. That simulation mimicked the water currents that would flow around it in a real-world scenario. Next, the artists used the same approach for the channel bubbles, krill, and general detritus, to make them appear as though they were interacting realistically within a body of water.

"We took the opportunity to re-create the style of the cinematographer and what he created on the production side, placing our CG cameras onto the whales and using very wide fish-eye lenses," explains Hyde. "That, along with the effects, helped create a claustrophobic underwater feel and put the audience right there with the whales."

Indeed, water scale is always an issue, and it was here. However, it is the attention to detail that sells the realism. "You are constantly trying to get a realistic look with the scale of the water. And to a certain extent, you can push the simulation within the constraints of memory and time. But then you have to augment it with white water, foam, spray, mist, and so forth. That is generally what sells it at the end of the day," Hyde contends. "If you don't see those details, it does not sell the scale. We were constantly battling to get the scale and detail into the water."

For both the surface and underwater shots, secondary sims were generated for the atmospherics, like mist and spray. Primary sims were done on the whales to get the initial cresting and breaching, and then secondary sims were run to get the "sheet water" running off their backs as they crested. Simulations also helped achieve whitecaps, to make the ocean appear stormier.

Almost all those sims were accomplished in Houdini.

Overall, Hyde estimates the effects team generated more than a petabyte in water simulation data for the film. Fortunately, this amount of data did not sink the effects crew.

For the feature *In the Heart of the Sea,* some of the "Essex" crew overcame insurmountable odds and eventually conquered the elements, enabling them to eventually recount their harrowing journey. In Philbrick's and Melville's books, words are used to paint a vivid picture of this struggle. For the film, though, that task was given to the effects crew, which used state-of-the-art visual technology to bring this rich, visceral story to cinematic life. ■

Karen Moltenbrey is the chief editor of *Computer Graphics World.*

HARDWIRED

VFX EXPERTS RE-CREATE A HIGH-WIRE ARTIST'S THRILLING ACT IN *THE WALK*

BY KAREN MOLTENBREY

In 1974, high-wire artist Philippe Petit accomplished an incredible feat, crossing between the tops of the World Trade Center towers on a thin wire strung between the two buildings. His daring act is retold in the feature film *The Walk* from TriStar Pictures.

Bringing the story to the big screen required tremendous determination, will, and dedication to their craft by the filmmakers, visual effects artists, cast, and crew. The end result: Audiences felt as though they were on the ledge with Petit (played by actor Joseph Gordon-Levitt) when he took that first step, and then on the wire as he traversed the void 110 stories above 1974 New York City.

Forward-thinker Robert Zemeckis directed *The Walk*, while Kevin Baillie of Atomic Fiction served as overall visual effects supervisor. Atomic Fiction completed the majority of the work involving the walk between the towers and replacing a stuntman's face with that of Gordon-Levitt's. UPP in Prague was tasked with the nighttime rooftop antics, crafted a digital reproduction of Paris' Notre Dame cathedral, and made Old Montreal look like 1950s/1960s Paris. Meanwhile, RodeoFX handled the ground-level work, such as the Trade Center lobby and plaza, and the shots of Petit on the Statue of Liberty. Legend 3D completed cleanup work and did the 3D conversion of the film.

As the film is based on a real-life experience, re-creating reality was vital. And not just any reality. The entire set had to reflect true-to-life New York City – the towers and surrounding areas – as they were on August 7, 1974, when Petit took his famous walk. No small feat considering the scope of the work and the emotions the structures invoke following their destruction on 9/11.

"We felt a lot of responsibility toward doing it right. We wanted to do justice to the towers and represent them in a way that was respectful and accurate, and would portray them in a positive light. This movie is a love letter to the Twin Towers," says Baillie.

THE TOWERS

The World Trade Center, which comprised seven buildings in Lower Manhattan, was constructed over two decades starting in the late 1960s. The centerpieces were the Twin Towers. The original One World Trade Center (the North Tower), when completed in 1972, stood at 1,368 feet, while its twin at Two World Trade Center (the

DIGITAL ARTISTS HAD TO RECONSTRUCT THE TWIN TOWERS OF THE WORLD TRADE CENTER IN EXACTING DETAIL FOR *THE WALK*.

South Tower), completed in 1973, was 1,362 feet high. They were the tallest buildings in the world at the time of their completion and boasted 110 floors.

That height had a major impact on the film's story line. "Sometimes movie reality is an exaggerated version of real reality," says Baillie. "But what [Petit] did was so crazy in and of itself that we didn't need to exaggerate the buildings in terms of their height."

According to Baillie, the tops of the towers in the movie were "exactly as tall as they were in real life, and what you get to experience up there on the wire [in the film] is what you would have experienced out there in 1974." The VFX artists worked from the actual architectural blueprints to reconstruct the buildings digitally "in their most perfect sense."

To that end, the group spent weeks with each panel and window, introducing slight imperfections. "It's that personal touch of introducing human imperfections into this giant monolithic structure built by humans that made our CG structure look realistic," explains Baillie.

So, the artists built the most realistic version of the towers they could possibly construct, though there were instances that required judgment calls, since every reference photo showed a different aspect of the buildings. "There were times that if we turned left, they would have looked harder-edged, more menacing, and if we turned right, they would have been softer, more inviting. When that happened, we tended to turn right, hearkening more positive memories of the towers. And the void between the towers would be something that was calling to Philippe, rather than being menacing," explains Baillie of the direction the artists took.

Zemeckis's directive was that the towers had to look 100 percent real, but they also had to be a supporting character, not an antagonist – they beckon and call to Philippe. "The height is terrifying in and of itself, especially if you see the movie in 3D," says Baillie, "yet it feels inviting in a way."

When Gordon-Levitt steps out onto the wire, there is a beautiful orange fog that clears from below, and the lighting at the start of the walk is at magic hour, with pink and orange flints off the building.

"It is a kind of magical moment that is meant to feel more like a ballet than anything threatening. But at the end of the walk, there is a sequence when [Gordon-Levitt] begins to have doubts and feels like the towers may have had enough and are telling him to get off his wire," says Baillie. "It is at this point when we made the weather a little stormier and the lighting grayish. The towers have not turned on him yet, but they are getting a little impatient."

CIRCA 1974

A great deal of research was done to achieve the desired level of realism. Baillie and the artists looked at reference photography in books and at Google images, as many people had posted pictures of the tops of the towers from various time frames. "But it was not until right after we finished shooting when the full gravity of what we needed to do really hit me," he says. That was when Baillie and others spent two days taking reference footage from a helicopter to see, for instance, how light changes within the city, how traffic moves at various times of the day, and so forth.

As if re-creating New York City from scratch wasn't daunting enough, the group also had to turn back the clock to 1974. "It looks totally different there now, obviously," says Baillie. "We had hovered [in the helicopter] in the exact position where Philippe had been when he walked between the towers, and I remember looking down and becoming overwhelmed by this simultaneous feeling of awe and respect at what he had done, and also the sheer terror of how high we were."

That was when Baillie realized the importance of integrating that emotional sensation of danger and awe into the film through the visual effects. "If a shot didn't make me feel that, I knew something was wrong and we had to figure it out," he adds. "It had to be technically accurate and emotionally accurate, too."

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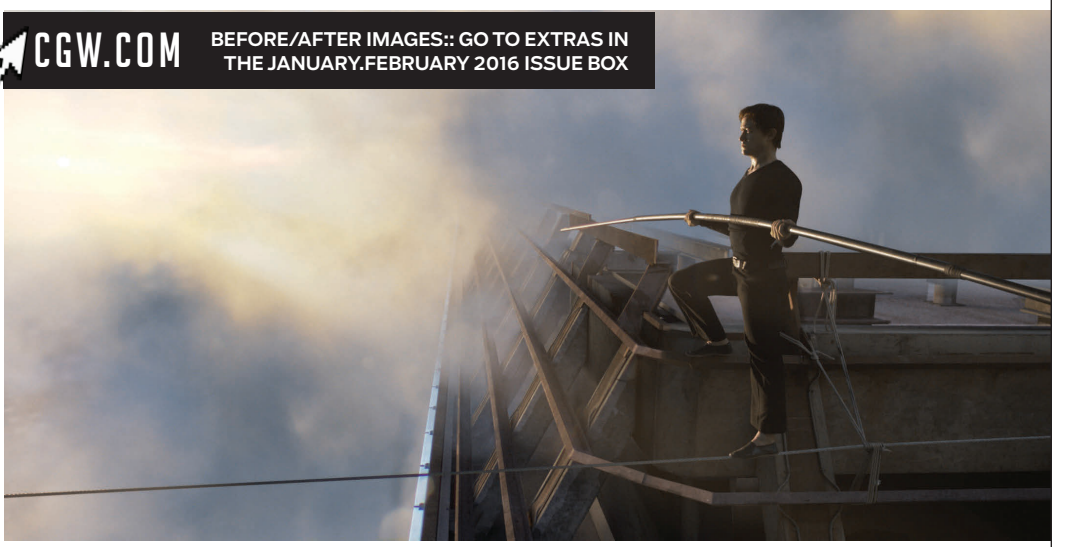


FILMMAKERS USED VARIOUS METHODS TO PORTRAY THE VERTIGO FEELING ON THE WIRE.

Had the artists been re-creating modern-day New York City, they could have used film and photographs taken from the helicopter. However, the city today looks very different than it did four decades ago. Fortunately, the team had access to tens of thousands of period photos, yet most were of poor quality and grainy, as this was before digital photography.

"A big creative challenge for the team was using a combination of old photos and blueprints from outside and inside the structures, to reconstruct the buildings, including every AC unit on the roof, the rain gutters, and the hot dog stand on the street. We even [digitally] added the newspaper stands on the ground and inserted newspapers from that time," Baillie says.

The artists constructed office interiors for the top 30 floors, including desks, bookshelves, blinds, and so on. "There is all kind of stuff in there to give that extra level of depth," Baillie says. "That's the thing about looking at reference photography: Every photo will have this one little thing that you can unearth, if you pay close enough attention, that will make it one percent more real. And another photo will do the same. So by the end of the day, you will have uncovered 40 to 50 things that can make very subtle and almost imperceptible changes to the imagery you are creating, but it will make the difference between good CG and realism. We spent a lot of time getting that last 10 percent of realism, to make people feel like they were really there."

UNDER CONSTRUCTION

The digital artists used Autodesk's Maya for building the models and The Foundry's Mari to texture them. Lighting was done in The Foundry's Katana, which was also used for all the scene construction and building assembly. Rendering occurred within Chaos Group's V-Ray.

As Baillie explains, so many people have different ideas of what the towers looked like – some thought they were white, others gray; some thought they had a blue tint. That's because the structures were made from anodized aluminum, so if they were viewed straight on, they appeared to have a matte silvery look, like a MacBook; from the side, they looked more chrome, almost reflective.

This resulted from thousands and thousands of tiny bumps on the surface across every square inch of the buildings that scattered light.

"The buildings were like chameleons, taking on the look of the environment," Baillie explains. "So on a sunny day, they looked white, but on a dreary day, they almost looked charcoal gray. We had to figure out how to reproduce that."

The solution was Sergey Shlyaev's GGX shader for V-Ray, a physically correct shader that utilizes microfacet distribution for better matching the measured response of real light transmission from real surfaces. In short, it simulated all those tiny bumps (boxes) on every square inch of the building surface.

"When we started using the GGX shading model, the towers transformed from good-looking VFX metal to something far more realistic," says Baillie.

This was important because the towers were taking on the environment around them. "Often with movies, you focus on what is in camera. Anything above or below us we don't worry about," Baillie explains. "With the towers, we had to worry about what was above, below, and behind us because it was all a set and reflected in the buildings. We had to build the world in 360 degrees. The towers themselves depended on us building a realistic world around them. We couldn't think of the towers or New York on their own, but how they lived together in the same world."

This resulted in a massive amount of rendering. "We are up on the towers for a long time, over 20 minutes of the film. So we had to figure out how to get all that rendering done," Baillie notes.

The team opted for a cloud-based rendering solution, using a platform called Conductor to manage the workflow, which enabled the artists to access and interface via the cloud with up to 15,000 processors on demand.

"This was the largest use of cloud computing ever on a movie," says Baillie, noting the film required 9.1 million hours of rendering in the cloud – basically, more than 1,000 years using a single processor. "So you could say we spent a millennium in the cloud creating the visuals."

According to Baillie, the film's budget was far less than other VFX-heavy features, but by using the cloud, they were able to turn around the work quickly, saving an estimated 50 percent in rendering costs compared to using traditional methods.

Also atypical was the use of matte paintings on the film. When Gordon-Levitt steps out onto the wire, it is sunrise, but as the walk progresses, the sun gets higher in the sky, and by the end, the environment is stormy. A pure, traditional matte-painting approach would have required close to 20 paintings, "which would have been completely overwhelming," says Baillie.

Instead, the artists followed a hybrid approach whereby the CG lighting and matte-painting departments worked in concert. Since every detail below the wire was geometry, they could blend the light bouncing off these very detailed, live-rendered CG assets with matte-painted augmentations, and change the CG light as the sequence progressed. The end result contained the beauty of a painting with the flexibility of CGI.

VERTIGO

Baillie points out that *The Walk* is one of the great successes that happens when all the departments work together in perfect sync: production, set design, digital effects, camera, stereo 3D. To prepare for the walk, a 40-by-60-foot corner of a rooftop – about a sixth of the actual size – was used for

FACIAL EXPRESSION

Preparing Actor Joseph Gordon-Levitt for death-defying scenes

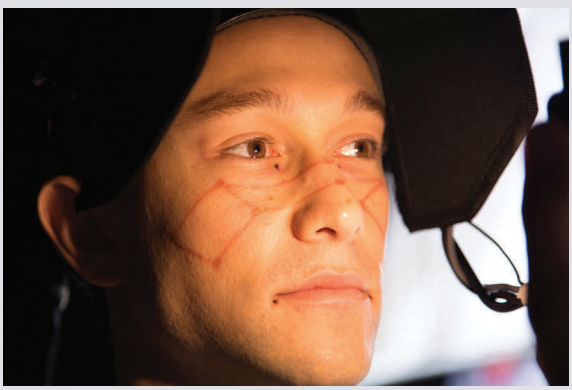
Digital artists at Atomic Fiction created a CG version of Actor Joseph Gordon-Levitt's face for scenes that required a stunt performer.

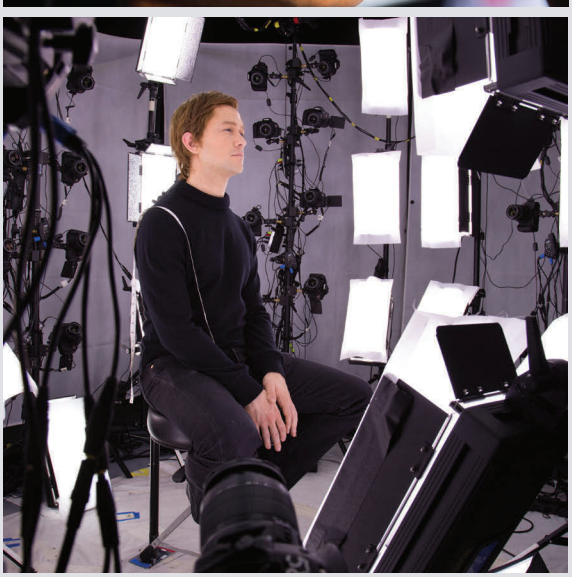
The scanning was done at Pixelgun Studio with a mobile photogrammetry rig that captures ultra-high-resolution facial expressions and full bodies. The solution utilizes an array of more than 100 cameras that surround and simultaneously photograph the subject. Proprietary software uses perspective differences among the cameras to construct a perfect geometric representation of the face, and since cameras are used as the source, the texture perfectly aligns to the mesh.

In a half hour, the group acquired 40 to 45 poses of Gordon-Levitt's face. "We had him act out poses where we may have needed to re-create his face as he performed on the wire," says Atomic Fiction's Kevin Baillie, overall visual effects supervisor. "It tells us how, when he furrows his brow, blood flows from his forehead to his temples; what the skin and blood under the skin do. Just as reproducing the offices and the bumps on the surface of the towers elevated the reality of the environments, so did this information for the performer. Every single detail on the skin and under it increased the level of reality."

The resulting mesh and textures provided the artists at Atomic Fiction with substantial data that was later refined artistically and with the use of Chaos Group's V-Ray skin shader. "We've learned over the years that reality is not always the right answer; it's what looks right," Baillie says.

On the last day of filming, Gordon-Levitt donned a Faceware Technologies helmet camera for approximately 50 takes that replicated moves by the stunt performer which likely would require face replacements in the shots. "Joe walked across a tape mark on the ground with the head cam, and Faceware gave us very clean and lightweight data to use," says Baillie. "It got us 60 to 70 percent there, as opposed to a detailed motion-capture session with thousands of markers, which would have been data overload and required more time for us to undo than to animate the shot."





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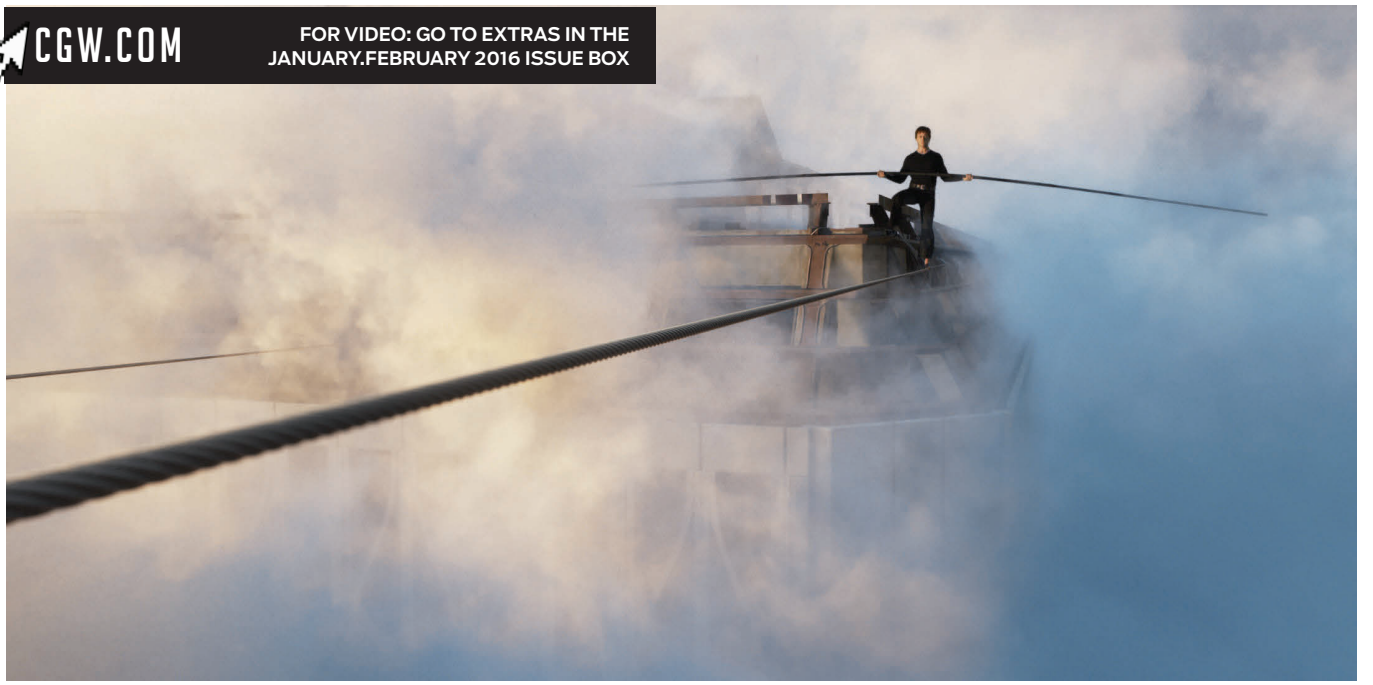

TO ILLUSTRATE THE NOTION OF HEIGHT, ARTISTS ADDED VARIOUS EFFECTS, INCLUDING CLOUDS, USING HOUDINI.

the actors to scamper across and for the camera crew to capture their viewpoint in the rooftop scenes.

Zemeckis, Baillie, and Cinematographer Dariusz Wolski primarily relied on two specific types of camera moves to produce the dizzying, vertigo effect. One is when we are looking at Gordon-Levitt on the wire and see the horizon, and the camera moves above him and starts looking downward. The other starts with the edge of the building in frame and moves over it, as if daring us to peer over the edge. Later, Jared Sandrew, 3D supervisor for Legend 3D, picked up on those cues and accentuated the vertigo feeling in the stereo conversion process.

"There were times in the movie when we didn't want people to feel that way, so we made the 3D feel shallower. If Petit (Gordon-Levitt) was feeling serene and comfortable, we wanted audiences to feel that way too," says Baillie.

According to Baillie, "there were a bazillion little things we added to sweeten the look," such as clouds that would blow by in many of the shots to provide depth. Flocks of birds would fly past, stacks would release smoke in the distance, and further down ant-size people would walk down the street and steam vents would release vapor. A lot of these effects were generated in Side Effects' Houdini, though the birds were done in The Foundry's Nuke 3D particle system.

A method of creating haze in the city also helped sell the illusion of height. "If you look at a photograph, it's not just the intensity of the haze that changes as you go off into the distance, but the color of the haze changes, too," says Baillie. "It is a little warmer closer to the sun, cooler and bluer over the water than over the city, where it might be a little brown." To this end, the group developed a system within Nuke that used Nuke 3D with the renders so the artists could control the depth of the haze and tweak the fine grain in the way they do color.

"We blurred the line. Nuke for us is no longer a tool that is just used for 2D comp; it is used heavily in 3D to solve the illusion," says Baillie.

SET PIECES

Before filming began, Gordon-Levitt was given tightrope lessons from the best – Petit himself – enabling him to do limited walks 12 feet off the ground. For more complex work, a steel plank with a groove in the middle was situated under the wire, giving the actor more support and stability; later, the plank was digitally erased and the sides of the actor's feet were rounded out, making it appear as if they were supported solely by the wire.

As for the towers, the artists re-created the entire structures with geometry, but the top 30 stories and bottom 30 – which are seen in the film – contained far greater detail. In short, if audiences could see inside the windows, an office was made inside.

Indeed, the towers – which no longer stand – were the biggest visceral aspects of this virtually constructed world. However, they were not the only CG sets. The movie was filmed in Montreal, which had to stand in for NYC and Paris, where Petit had spent his earlier years. Many locales were all-digital built by RodeoFX or UPP.

According to Baillie, the work on *The Walk* was among the most satisfying he has done. "Lots of movies are fun, but they are more about creating an effect that is an obvious effect," he says. "For this movie, the goal was to have the effects serve in a supporting role rather than stealing the show. They sit in the background and are there to transport the audience and make them feel like they are there with Petit [Gordon-Levitt], a place that is very special to many across the globe." ■

Karen Moltenbrey is the chief editor of *Computer Graphics World.*

ARCTIC BLAST

FOR *NORM OF THE NORTH*, SPLASH ENTERTAINMENT PROVES THAT INGENUITY AND DETERMINATION CAN LEAD TO SUCCESS

BY KAREN MOLTENBREY

The Arctic is home to an abundance of living creatures: polar bears, walruses, narwhals, beluga whales, reindeer, caribou, lemmings, and more. However, it is not a place for humans. At least that is the opinion of Norm, a polar bear of many words, especially on the subject of tourists invading his home in the Arctic.

When a maniacal developer threatens to build luxury condos in his backyard, Norm heads south to New York City on a hero's journey in an attempt to put a halt to those plans and save his homeland in the 3D computer-animated adventure-comedy *Norm of the North*, directed by Trevor Wall in his feature-film directorial debut.

Norm is produced by Splash Entertainment, in partnership with Assemblage Entertainment, and distributed by Lionsgate. Splash (formerly Mike Young Productions and Moonscoop US) specializes in children's entertainment, encompassing a wide spectrum of productions, from television to now feature films with the debut of *Norm*.

With their respective expertise in broadcast, Wall and Splash turned to what they knew best, approaching the feature's workflow as they would a television production. "We had a short schedule and a modest budget, and this was the fastest, most efficient way to do things," says Wall.

At a feature animation studio such as Disney or DreamWorks, for instance, storyboarding starts with a scratch track, a sound recording used as a temporary placeholder until the animatic is locked down for the voice actors. For *Norm*, the crew followed more of a TV approach, moving from script to recording the voice talent, and then storyboarding from the actors' track.

However, unlike broadcast, there was no juggling of multiple scripts and productions, affording the crew the luxury of focusing solely on the movie.

Work on the film was divvied up among coproduction partners across the globe. The storyboarding occurred at Splash in California. The post sound effects and pre-mix were done at Telegael in Ireland, as were preproduction of original backgrounds and orthographics for the characters based on concept designs developed at Splash. Animation was handled

at Assemblage in India, and a smaller portion was done at a studio in China (GDC's Institute of Digital Media Technology). Postproduction work, meanwhile, was completed at Splash.

"I would check in with the animators in India and China every week to talk about a scene, and they would model the characters and backgrounds, and push that through from layout to final color," says Wall.

Arnaud Mathieu started out as animation supervisor, overseeing the work at Assemblage; later, his role shifted to assistant director.

Working in vastly different time zones made *Norm* a 24-hour-a-day job for Wall and the others involved. Most of the communication was done via Skype, and dailies were sent each day. The groups also used The Foundry's Hiero shot management, conform, edit, and review solution extensively, for basic editing and shot review, "which considerably smoothed the follow-up on the shot versioning," says Mathieu.

WHAT A CHARACTER!

Norm is a polar bear with a big personality. But he is complex in other, more technical ways. He has the ability to walk on two legs when taking on human attributes, such as dancing, and of course, embarking on his NYC adventure. When he is in polar bear mode, he is a quadruped, such as in scenes where he is interacting with his father.

In addition, Norm is covered in thick, white fur. In fact, a number of the characters in *Norm* are furred creatures, including Norm's sidekicks, a trio of lemmings, as well as caribou and other lemmings. To handle the fur, the Assemblage artists used Joe Alter's Shave and A Haircut hair modeling and animation software.

Norm had roughly 1.5 million hairs. If this wasn't complicated enough, he was often wearing clothes or interacting with props. In a storm sequence, the fur was wet, presenting a separate challenge. As a result, the character had various grooming requirements, depending on the situation and scene.

The number of furred characters in a particular scene affected how the shot was rendered. At times, the crew used cloud rendering, giving them access to several thousand render blades.

"We also created simpler shaders to imitate the fur for background characters in some of the shots of the Norm crowning sequence with all the furry characters in the cavern," says Mathieu.

The evil villain, Mr. Greene, meanwhile, is a new-age executive-turned-guru with long charcoal hair. Animators gave him a lot of cartoony squash-and-stretch capabilities, with extreme poses, antics, expressions, and so forth.

Assemblage created these models using an Autodesk Maya-based pipeline. Animation was done in Maya, as was the lighting. Maya's built-in Arnold (from Solid Angle) was used for rendering, while The Foundry's Mari was employed for texturing and the company's Nuke for compositing.

On the hardware side, Assemblage used dual-Xeon workstations with 32GB of RAM and Nvidia graphic cards. The network architecture at the studio relied on Isilon storage, which offered efficiency and stability.

Some scenes even required crowd control – to handle the mobs of people and the heavy car traffic in NYC, for instance. This was done with Golaem Crowd simulation software that's built into Maya.

"The extensive use of crowds in NYC pushed us to find different solutions for the dancing sequence in the city, without compromising the quality. For example, lots of animation cycles were generated to fit the mood of the crowd at different parts of the plaza sequence. We sent the cycles to Golaem, which handled the crowd on a shot basis," explains Mathieu. "This gave us the flexibility to arrange the crowd per the artistic requirements."

However, the animators, working in tandem with the director and the crowd VFX team at Assemblage, had to change a few camera movements and framings in the sequence so the shots could be delivered on time.

ENVIRONMENTAL CONCERNS

Norm contains a wide assortment of environments and backdrops, including various locations in the Arctic (Pride Ice, Grandpa's land, and the shore, to name a few) and in New York City (such as Times Square, Greene Square, the warehouse, Mr. Greene's building, various streets, and more). Altogether,

(LEFT TO RIGHT) SQUASH AND STRETCH WAS USED FOR THE EVIL DEVELOPER. OTHER CHARACTERS, LIKE THE LEMMINGS, NEEDED FUR.

artists constructed more than 600 buildings – a low number compared to some features, but a difficulty for the small crew working on this film.

"New York City was one of our main challenges," says Mathieu. "We needed to re-create a complete and personal version of the city, in sync with Wall's view. The GPU cache of Maya helped a lot in this regard, whereby NYC was divided into several different zones that were loaded into Maya depending on our needs. To help the production flow, we also had to create matte paintings that were used in some shots to show the buildings in the background. Trevor [Wall] wanted to give the feeling of a very dense city that was really lively, with lots of cars, crowds, and buildings."

The modelers at Assemblage used Pixologic's ZBrush, mainly for the detailing work on the sets in the Arctic. "Lots of the mountains were detailed in ZBrush and rendered with displacements in Maya, giving the environments a more lively and natural look," says Mathieu. "Although this produced heavy scenes with long render times, we wouldn't have been able to achieve the look and feel Wall wanted otherwise."

The effects artists had their hands full, too, creating water, snow, ice – "just about everything except fire," says Wall.

Snow proved a big obstacle, making the Arctic scenes especially complex. These effects, as well as most of the movie's VFX, were achieved in Maya. To add footprints in the snow, the group first employed an automated system that was based on the position of the feet by the characters making the tracks, along with displacement on the surface. It also worked for characters sliding on the ground.

However, the artists realized that the creation of those footprints needed a little more precision on close-up shots. So, the system was improved to get a smoother creation on the surface.

Water effects were tricky, too, generated with Maya Fluid as well as Side Effects Software's Houdini. According to Mathieu, the water simulations involved a great deal of surface area and detail, often resulting in sims that took three to five days to compute.

Water was a major occurrence in a giant storm sequence near the end of the movie, with rain, lighting, splashes, wind. It is the sequence in *Norm* that Wall is most proud of. Vayu Digital in Mumbai created the simulations for the storm, working in sync with the animation department at Assemblage to match the animation of the boat.

"When you read a script where the main furry characters are living in the Arctic, going to New York City, and sailing into a storm on a huge barge in front of a tidal wave, you already know that you're going to spend a lot of time in the office," says Mathieu. "What I mean is, given the production constraints and the time, there were many obstacles on this ambitious project. But all the studios and everyone – from Splash CEO Nicolas Atlan [who stayed in contact with the production team and regularly visited Mumbai] to each and every artist – met those challenges head-on."

THAT'S A WRAP!

Assisting in the production of *Norm* in LA were two animation veterans from Disney and DreamWorks, who Wall says showed him how other studios approach CG features. "I learned from them the right way to do things on a feature film," he adds.

(TOP) NORM IS A BIPED WHEN ACTING HUMAN-LIKE. (BOTTOM) MAYA FLUID AND HOUDINI WERE USED TO GENERATE THE CG WATER.

Assemblage's CEO, Max Madhavan, also hired several leads, production managers, and a new COO, Milind Shinde, all coming from DreamWorks, who brought their expertise and experience to the project.

According to Wall, the tight schedule was the biggest looming issue for everyone involved. At one point, the filmmakers held their breath for an entire week, fearing something devastating had happened to the movie halfway through production following a fire at Assemblage.

"We were already on a tight schedule, but they stepped up, worked day and night to fix everything, and in less than three days had everything back on track," Wall says.

Wall believes audiences will embrace *Norm*. "It has a basic but heartwarming story that will be liked by children and adults. It also has entertainment value," he says. "I am proud of the entire film."

Wall will be returning to broadcast work, but has since fallen in love with moviemaking, breaking the ice, so to speak, with *Norm*. In fact, he, along with many of the others who dipped their toes into the frosty waters of animated feature filmmaking with this project, are not that dissimilar from the characters in the film, who determinedly set out on a big adventure into unknown territory for something they believe in. And now we can enjoy the results of that journey in theaters. ■

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Karen Moltenbrey is the chief editor of *Computer Graphics World.*

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VIRTUAL REALITY ISN'T COMING; IT'S ALREADY HERE, WITH NEW APPS, NEW HARDWARE, AND NEW USE CASES ARRIVING EVERY DAY

BY JON PEDDIE

If you haven't heard of virtual reality.... Okay, wait a minute. I don't believe that's possible, not for anyone reading this magazine. You can't avoid it. It's the headline story in almost every Web page and newspaper, and featured in dozens of TV shows and movies.

As many predicted, VR was the featured topic at last year's SIGGRAPH, and suddenly all those other hot young things from a few years back have cooled down. For years, we have argued that there is a practical consumer market for 3D content creation because the tools are so hard to use. That is changing as the tools are changing, and it's the makers who are changing it.

But, I would argue all that is nothing compared to the change that is being wrought by VR. No matter how the huge surge in interest plays out in the long run, VR is stimulating content creation in 3D, and content is what it will take to make the technology successful.

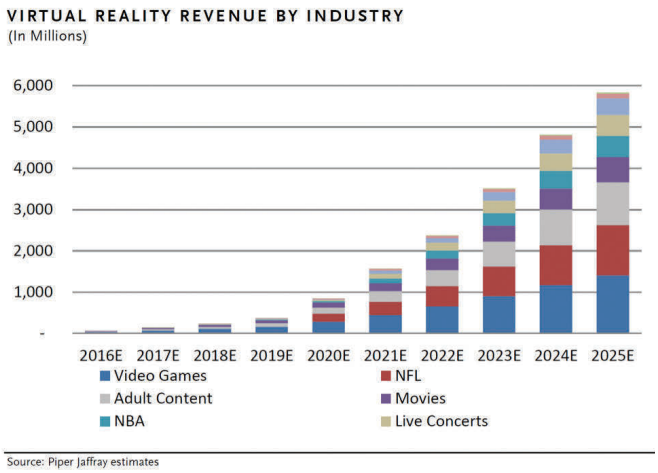
What propelled VR into the headlines was the $2 billion acquisition of Oculus by Facebook.

"We're going to make Oculus a platform for many other experiences," said Facebook's CEO Mark Zuckerberg while announcing the deal in 2014. "Imagine enjoying a courtside seat at a game, studying in a classroom of students and teachers all over the world, or consulting with a doctor face-to-face – just by putting on goggles in your home. This is really a new communication platform."

Some people are skeptical about Zuckerberg's vision. In general, people don't like to wear goggles or glasses in their homes. It's one of the reasons 3D televisions have never taken off.

Nonetheless, one of the reasons VR is getting so much hype is because it has traction – there is infrastructure for content creation, there is a base model in games and VR adds value (for some gamers), and perhaps even more important, VR is stimulating the development of new media forms. In addition, content creators are finding VR to be a useful tool to create content, and last – but absolutely not least – interest in VR is broad and crosses many markets, from games, to movies, to design, architecture, and manufacturing.

Predictions of the size and expanse of the VR market all indicate phenomenal growth and opportunity in all types of entertainment markets.



THE RIFT HEADSET GOT GAMERS EXCITED ABOUT VR, BUT MANY OTHER INDUSTRIES ARE INVESTED IN THE TECHNOLOGY.

MORE THAN ENTERTAINING

VR isn't just for entertainment, although that's certainly going to be the most attention-getting use, and potentially the most dangerous for disappointing the consumer and having them turn away from it, as they did with stereo 3D.

VR is not new, which most people know. It has been employed in non-consumer applications for decades, and still is. However, the volumes have been small and the systems specialized and usually expensive. But the people and organizations that bought and continue to buy those VR systems – the professional-use cases – did so because VR solves real problems, primarily as a tool for exploration and sometimes inspection.

One major use of VR, especially by industry and defense contractors, is the visualization of large, expensive projects by many people, all at the same time and all looking at different parts. Big-budget projects can be explored virtually without investing in physical prototypes. Using the basic models developed in CAD systems, engineers, managers, and contract administrators can see how the project will look. This is not new, as visualizations and animations have been used for years to test designs, find conflicts and interference from adjacent parts,

VR WAS A BIG TOPIC AT SIGGRAPH 2016.

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and to test for buildability and user access. However, they used flat screens, and sometimes CAVEs, and were limited to the view provided by the driver of the simulation.

VR also has been used to train surgeons and medical students. Surgeons, using MRI 3D models, practice an operation before cutting open the patient. Knowing where vital organs or damaged portions are without having to explore in real time saves operating time and is less stressful for the surgeons and the patient.

A surgical operation is intricate and intimate by nature, and a lack of space and vision of the operation by anyone other than the surgeon is often difficult, so students usually do not get a good view of the procedure. This is especially the case in crowded operating rooms where surgical trainees perform multiple duties. Using a VR headset and a specially developed app, trainee surgeons can gain close-up, 360-degree views of a surgical procedure.

Industrial, scientific, and engineering examples abound, as well as training and maintenance applications. One of my favorite examples of training is for welding. Welders are trained to wear a mask, so what better tool to train them than a VR headset.

However, with the advent of Facebook-backed Oculus and competitors, VR is no longer just the preserve of large corporations and research centers. The ability to use parts that have been reduced in cost for mobile phones (like accelerometers and small high-resolution displays) has reduced the barriers to entry, and as a result, VR technology has become democratized. As cost goes down, demand will go up, and if the content is delivered, and meets user expectation, then VR will definitely be a component of our lives for quite some time. ■

Jon Peddie (jon@jonpeddie.com) is president of Jon Peddie Research (JPR), a Tiburon-CA-based consultancy specializing in graphics and multimedia that also publishes JPR's "TechWatch."

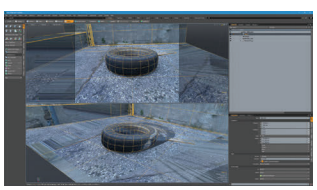
SOFTWARE

DIGITAL CONTENT CREATION

More Modo

The Foundry has introduced Modo 902, which adds a focused tool set for digital matte painting and virtual camera creation, making it faster and easier to match the authentic with the synthetic. Users can now create virtual cameras that match a still image simply by drawing on screen. They also can project images into texture channels or use a special projection shader. Projection ink can be used to paint textures directly onto UV-mapped geometry. The upgrade is free to Modo 901 users.

www.thefoundry.co.uk



Max Extension

Autodesk has launched 3ds Max 2016 Extension 2 for 3D modeling, animation, and rendering. Extension 2 features a number of improvements. Max creation graph enhancements allow users to create, manipulate, and use shapes and splines with new nodes. Pros can also import bitmaps and simulation data like CSV or Open VDB files. Print Studio allows users to export 3ds Max files for 3D printing in one swift click. And animators can now import and animate accurate simulation data to visualize how it changes over time. New text and shape map tools allow animators to use objects as a mask to create custom decals, graffiti, and other text-based graphics on the fly without leaving 3ds Max. Also new is the ability to easily and accurately create, place, and animate multiple materials, and use any shape to control the application of materials to an object.

www.autodesk.com

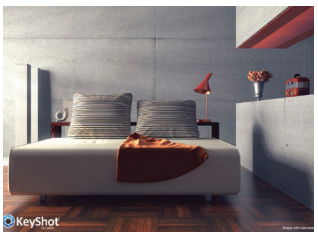
RENDERING

Give it a Shot

Luxion, maker of KeyShot, the real-time raytracing and global illumination application, has released KeyShot 6, which refines the rendering workflow with reduced complexity and advanced features. Additionally, KeyShot 6 is now optimized for interior renderings, including complex interiors with indirect lighting, with an all-new material graph that allows complex material creation, including roughness mapping for weathered materials and material animation.

Luxion also has introduced new product structure and pricing for KeyShot HD and KeyShot Pro Editions. KeyShot HD now comes with unlimited real-time rendering and output resolution and remains priced at $995. KeyShot Pro now includes KeyShot Animation, previously a $500 add-on, and remains priced at $1,995. Animation will no longer be available as an add-on for new purchases of KeyShot. KeyShotVR and all KeyShot Network Rendering options remain available as add-ons for all editions of KeyShot.

www.luxion.com



MIDDLEWARE

For Small Studios

IKinema has introduced a small-studio version of its full-body IK RunTime middleware. RunTime-Indie is targeted at small, independent studios and is technically identical to RunTime, the full-body solver used by top publishers to create convincing and realistic motion for characters during gameplay. Integrated with Unreal Engine 4, RunTime enables characters to react naturally to ever-changing terrain and environments, and scale obstacles with ease in real time. As a result, VR and game developers are able to deliver realistic animation with believable characters. IKinema has also announced the addition of a full rig editor to both RunTime and RunTime-Indie, enabling developers from studios of all sizes to rig characters – whether human or fantasy – without the use of third-party tools. Instead, they can rig directly within the engine, modifying assets and unlocking game play, from locomotion, climbing, and foot placement, to pointing props and weapons, reaching, and so forth.

www.ikinema.com

HARDWARE

WORKSTATIONS

@Xeon

@Xi Computers has unveiled a new MTower line of workstations based on overclocked Intel Xeon processors. Xi MTower workstations sport the latest V.3 edition Intel Xeon 1650 and 1660 processors, clocked at over 4 GHz and configurable with the newest generation of Nvidia Quadro Maxwell video cards. Single-socket, Xeon workstation performance is now delivered by the Xi MTower PCIe, with a full eight-core clock speed of 4.10 GHz and four-channel interleave 2133 DDR4 scalable to 64GB. These new Xi Workstations can be custom-configured and ordered directly from the company's website.

www.xicomputer.com

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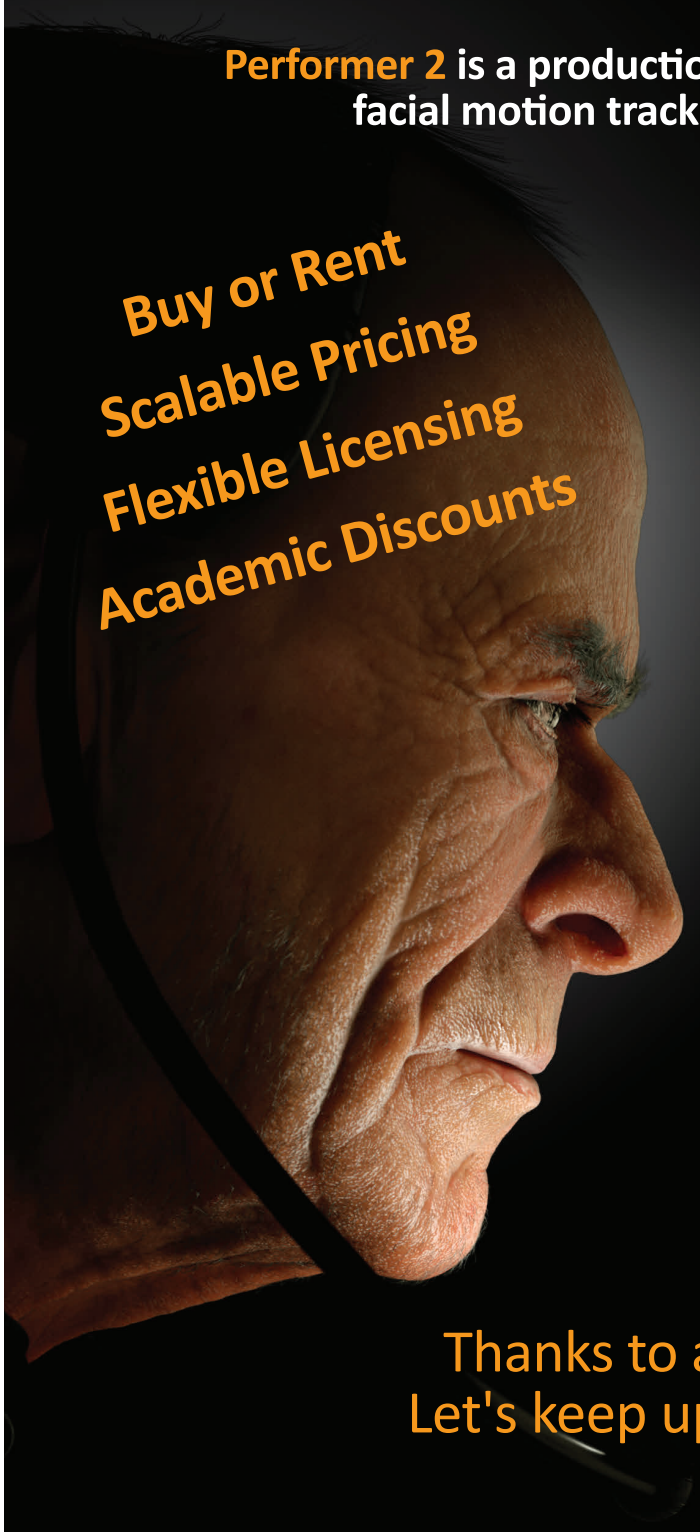

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